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FORT EUSTIS, VIRGINIA

JUDGMENT OF VOLUME FROM PHOTOGRAPHS OF COMPLEX, IRREGULAR SHAPES

March 1963

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TRECOM Technical Report 63-

prepared by :

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PHOENIX, ARIZONA
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FSF

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JUDGMENT OF VOLUME FROM PHOTOGRAPHS OF COMPLEX, IRREGULAR SHAPES

AvCIR 61-18

By

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for

U. S. ARMY TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

FOREWORD

This report is based on a dissertation submitted in partial fulfillment of the requirements for the Ph. D. degree from the Department of Psychology, Carnegie Institute of Technology.

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SUMMARY

Accident investigation procedures involve estimates or judgments of damage to the aircraft. One aspect of these postcrash observations of particular relevance to crash injury studies is the reduction in volume of the occupiable area. It has been proposed that a panel of analysts, working from photographs, could provide more accurate and reliable estimates of such characteristics than would a single field investigator working under uncontrolled conditions. The present study examines the feasibility of making judgments of volume reduction, a three-dimensional problem, from two-dimensional representatives of objects, and attempts to identify the perceptual factors that might influence such judgments.

Hypotheses regarding the role in such a task of such factors as number and angular disparity of photographs, the stimulus complexity (i.e., damage characteristics) of the object, the geometric properties of the intact object, and changes in memory for visual forms were submitted to empirical analysis in a laboratory study in which 279 college students judged from photographs the volume reduction of damaged metal containers. The independent variables included number of photographs (two, three, or four) and angular disparity (low, moderate, or high). Photographs of 40 damaged containers, 10 for each of four different types of objects - cylinder, cylindroid, rectangular-base box, and square-base box - were assembled into notebooks to correspond to the nine cells of the experimental design in order to test subjects in groups. Subjects made their judgment of volume reduction to the nearest 5 percent on a rating scale.

Comparison of the constant errors in judgment revealed accuracy to vary significantly as a function of angular disparity and the stimulus characteristics of the individual objects. Analyses performed on the average errors demonstrated accuracy of judgment to vary as a complex function of the number of photographs, angular disparity, type of object, and degree of damage. In general, three photographs provided the most accurate judgment. Judgments of volume reduction of low-damage stimuli were generally more accurate from groups of photographs having low angular disparity, while those of high-damage generally were better at higher angular disparities. Two dimensions along which three-dimensional shapes might be scaled were identified: the volume reduction of "square" objects was judged more accurately than that of "round" objects; while those objects with symmetrical bases were judged more accurately

than those with unsymmetrical bases. The generalization was offered that more complex shapes contain greater information; and, thus, more and different views are requisite to provide valid transmission of this information to the observer.

Individual observers were found to be reasonably consistent from one type of object to another in over- or underestimating volume reduction. An average correlational index of .71 was obtained. The estimate of single-observer reliability for volume reduction judgments was .64.

Additional research is indicated in order to determine the role played in judgments of volume reduction of additional variables falling within the areas of stimulus attributes, viewing conditions, and observer characteristics.

CONCLUSIONS

1. Accuracy of observers' judgments of volume reduction varies as a direct function of the amount of information provided by photographs and as an inverse function of the complexity of the stimulus object. Three photographs generally provided the most accurate judgment. Volume reduction judgments of low-complexity (i.e., low-damage) shapes were generally made more accurately from groups of photographs having low angular disparity, while those of high complexity were made better at high disparity.

2. Observers' judgments of volume reduction vary with the type of geometric shape rated. Objects with square edges were judged more accurately, overall, than were those with round edges. Objects with symmetrical bases were judged more accurately than were those with unsymmetrical bases.

3. Judgments of volume reduction, under the conditions of the present experiment, yielded a reliability estimate of about .64. If a panel of analysts were to make independent ratings of volume reduction, the number of raters required, so that the average ratings would have a reliability of about .95, would be 11. Clearly, a panel of this size is too large for economical processing of routine accident cases. We might expect that training and further refinements in the rating procedures would substantially improve the ratings.

RECOMMENDATIONS

1. The generalization that more complex shapes contain greater information and, thus, that more and different views are required for valid transmission of this information to the observer should be put to further test. More refined definitions of object complexity than used in the present study are possible in terms of such measures as lines, angles, and intersections. Study of the relationships between such aspects of complexity and judgmental accuracy is further indicated by the point that stimulus complexity, while in one sense making judgment more difficult, may make tridimensionality more apparent and thus, in turn, yield more accurate judgments.

2. Inasmuch as the observers in the present study had considerable difficulty in discriminating among the undamaged objects of similar shape, the unreliability in their judgments of volume reduction may be attributed in part to this failure in retention. A study of volume reduction judgments of complex, irregular shapes should be carried out with a degree of observer familiarity with the intact shape as a primary independent variable.

3. Psychophysical studies are indicated to determine when "just noticeable differences" in different, undamaged shapes are perceived; i. e., how much difference need there be in a dimension (height, width, depth) for A to be perceived as different from B? The role of size and shape constancy in this situation should also be evaluated through definitive study; e. g., when can a tilted cylinder be discriminated from a tilted cylindroid?

4. A number of variables whose role in judgment of volume from photographs was not considered in this study should be a part of further research in this area. These include:

    a. Detail resolution, depending upon the distance from which a photograph is taken.

    b. The angle with the horizon at which the photograph is taken.

    c. Context--judgments of a particular component may be influenced by the severity of the surrounding damage.

d. The "meaning" of damage--may vary from an investigator rating "extent of repair" to one concerned with crash-injury relationships.

e. Past experience in aircraft accident investigation, especially in evaluating damage.

5. If an analyst is to have available to him valid information from which to judge structural collapse or distortion, the photographer should provide, in addition to a standardized set of photographs taken at specified angles and distances around the wreckage, individual photographs taken at angles that are congruent with any unique aspects of the damage configuration.

6. This study, concerned with accuracy of observers' judgments of volume of complex shapes from photographs, should not be taken to imply that accuracy of ratings made "on-the-spot" by field investigators are, or are not, significantly superior to those made by office analysts from photographs submitted with accident reports. Once a clearer picture of the factors determining accuracy of volume judgments from photographs emerges, however, research bearing on this point should be undertaken.

INTRODUCTION

This study was concerned with the ability of observers to estimate the volume characteristics of complex, irregular shapes from photographs. Impetus for the study emerged from a concern for the accuracy of aircraft accident investigators' ratings (Reference 2). The quality of mass accident statistics is seen to be, in part, a function of certain factors that can influence human judgment in the investigation situation. For example, judgments can be expected to vary with individual differences in the training and experience of the investigators. The role of imperfect recall can enter the picture when the investigator attempts to arrive at a judgment at some point removed from the actual crash site. Lack of familiarity with the intact aircraft for purposes of comparison with damaged structures can be a further source of error in judgment. Thus, as a consequence of concern for these problems, it has been proposed that photographs should play a greater role in the damage evaluation process. In such an approach, judgments of damage would be made by a small, trained panel of analysts working from a standardized set of photographs taken by the field investigator.

The rating of damage from photographs can be viewed as a task in information processing. From one or more photographs, the analyst obtains cues of damage and, on the basis of his past experience in viewing damaged (and undamaged) aircraft, then estimates the amount of structural collapse or volume reduction of the occupiable area. The concept of volume reduction has meaning in crash-injury research because of its relevance to human survivability. In the present study, volume reduction is to be chosen as the dependent variable because it can be objectively measured as a criterion of damage. The task of <u>judging</u> volume reduction, however, can vary as a function of the geometrical characteristics of the structural area to be rated (e.g., nose, wing, fuselage), of the type of damage represented (whether due to tension, compression, torsion, shear, or buckling stresses), and of the degree of damage. In turn, the ease and accuracy with which an analyst's judgments of any particular configuration can be made depend upon the amount of information provided by the number of photographs submitted and the conditions under which they were taken. It is evident that a number of independent variables can be defined that would influence judgments of volume reduction from photographs. From a consideration of the relationship between potential independent variables and the perceptual and judgmental processes of the human observer, certain

hypotheses emerged that were then reflected in the design of a laboratory study.

The stimulus characteristics of the complex, irregular shape that appears in the photographs of a typical crashed lightplane attracted early attention. If the complexity of a shape were defined in terms of line segment and intersection characteristics, then the amount of unique sensory input providing information about the shape is likely to be high and, correspondingly, the observer's task is made more demanding. Hochberg and McAlister's hypothesis (Reference 4) that "the probability of a given perceptual response to a stimulus is an inverse function of the amount of information required to define that pattern" would be in accord with this position. The study to be described has accordingly been designed in part to test the hypothesis:

H:1 Accuracy in judgment of volume reduction of complex, irregular shapes will decrease as complexity (i.e., degree of damage characteristics) of the object increases.

In the proposed task of judging volume reduction from photographs, certain views of an object will undoubtedly provide more information about damage, and thus about its volume characteristics, than will other views, so one can hypothesize:

H:2 As the amount of photographic (i.e., two-dimensional representation) information concerning an object increases, accuracy in judgment of its volume reduction will increase.

Also of importance in determining behavior within the perceptual judgment situation is the role of the past experience of the observer, of his familiarity with the class of stimulus objects, and of his ability to recall them.

Consideration of the role of the observer's past experience with the particular stimulus class (i.e., damaged objects) and with judgmental situations in general suggests that some observers will have a tendency to overestimate and others a tendency to underestimate the amount of volume reduction.

H:3 Individual observers will be consistently high (or low) in their judgment of volume reduction.

A fourth hypothesis assumes that certain Gestalt factors (e.g., "good figure") operate on the memory process and influence reconstruction of the original intact object.

H:4 The judgments, made by groups of observers treated alike, of the volume reduction of different types of objects will vary as a function of the geometric characteristics of the objects.

Finally, considering the role of familiarity with the original shape and its relationship to the integrity of the memory process, it might be supposed that imperfect retention of the original intact object will be related to over- or underestimation of volume reduction of the damaged object.

METHOD

EXPERIMENTAL DESIGN

Three levels of each of two independent variables were defined as follows: Number of Photographs - 2, 3, or 4; Angular Disparity - the degree of separation between adjacent photographs - low, moderate, and high. Further definition of the levels of angular disparity will be made in the discussion of stimulus materials to follow. The two independent variables were arranged in a conventional 3 x 3 factorial design with 31 subjects to be tested in each cell.

SUBJECTS

A total of 284 volunteer subjects was obtained from undergraduate summer session courses in the areas of social science and education at Arizona State University and Phoenix College. Data from five subjects had to be discarded for failure to follow instructions. The average age of 119 male subjects was 25.9 years; the average age of 160 female subjects was 28.2 years. Except for the restriction that an approximately equal proportion of male and female subjects be assigned to each cell of the experimental design, the assignment of subjects to the test conditions upon their reporting to the laboratory was done without bias. Testing continued until the requirements of the experimental design were fulfilled.

STIMULUS MATERIALS

The stimulus shapes were chosen on the basis of a systematic classification of three-dimensional objects, of type of damage, and of degree of damage. Furthermore, because volume reduction is often an inherent aspect of damage severity, the observer's task was specified as one of judging the percentage of volume remaining for an object after damage; thus, there was the requirement of being able to measure the object's volume both before and after dynamic loads had been imposed upon it. The stimulus shapes were chosen from a list of geometric objects to be reasonably representative of the type of structures found in lightplane fuselage construction. These included four basic types: cylinder (C); cylindroid (E); and two "boxes", one having a square (S) and one having a rectangular (R) cross section. The actual stimulus materials were thin-walled metal containers (e.g., liquid detergent cans, talcum and baby powder cans) obtained "off-the-shelf" at drug and grocery stores. The liquid volume of each type was measured in milliliters using a graduated cylinder. Ten containers of each type

to be damaged were then subjected to one or more types of stresses (compression, bending, or torsion) to produce a test series of diverse appearance and reasonable spread of volume reduction. The new volume of these forty containers was then measured and the percent of volume reduction computed. The dimensions and volumes of the undamaged containers are given in Table 1. Volume reductions of the damaged containers appear in Table 2.

Prior to their being photographed, all containers used in the study were sprayed with aluminum paint to give a uniform appearance. A flat, white cardboard turntable, upon which the container was placed, was used to rotate each stimulus object through the nine angles at which it was photographed. A photograph taken at a right angle to the longitudinal axis of the container was arbitrarily defined as a 0-degree photograph, while one taken in line with this axis was defined as a 90-degree photograph. Display letters and numbers were used to identify each container and the angles at which it was photographed. In order to bring into focus both the front and rear edges of the container to be photographed, it was necessary to use a Kodak Master View Camera with a 10-inch commercial Ektar lens placed 9 feet from the object. Photographs were taken with the camera inclined 7 degrees above the horizontal. Three photoflood lamps were used to illuminate the object and the flat, white cardboard background, and were placed to eliminate shadows insofar as possible.

After developing, an appropriate number of 3" x 3" prints of each negative were made in order to satisfy the requirements of the experimental design. All photographs were mounted on flat, black paper and enclosed in transparent plastic protector covers for inclusion in three-ring notebooks. Nine "control" notebooks to be used in a retention test (to be described later) contained photographs of the undamaged containers shown in Figures 1, 2, and 3. The pages were arranged in the order: cylinder, cylindroid, rectangular-base box, and square-base box in five books; this order was reversed in the other four books. Note that the base views of only the cylindroid and rectangular-base box were included. The composition of the nine major test notebooks is seen in Table 3. Definition of the three levels of angular disparity should now be clear.

Prints of the damaged containers representative of the four basic types of objects are shown in Figures 4 through 7. Representative photographs of the remaining stimulus objects appear in Figures 8 through 11 and in the Appendix, Figures 18 through 21. The pages of each of the nine major test notebooks were randomized prior to each test session, and the new orders of the code numbers identifying the stimulus objects were entered on the rating sheets.

TABLE 1

CHARACTERISTICS OF THE UNDAMAGED CONTAINERS

Container	Base Dimensions	Height	Volume
Cylinder:			
A Control	68 mm. dia.	139 mm.	440 ml.
B Tall	68 mm. dia.	158 mm.	495 ml.
C Short	68 mm. dia.	122 mm.	375 ml.
D Wider Diameter	75 mm. dia.	142 mm.	560 ml.
E Narrower Diameter	61 mm. dia.	132 mm.	310 ml.
Cylindroid:			
F Control	38 x 76 mm.	126 mm.	275 ml.
G Tall	38 x 76 mm.	134 mm.	300 ml.
H Short	38 x 76 mm.	107 mm.	230 ml.
I Wide Base	47 x 78 mm.	127 mm.	345 ml.
J Narrow Base	32 x 78 mm.	123 mm.	220 ml.
Square Box:			
K Control	63 mm. sq.	132 mm.	470 ml.
L Tall	62 mm. sq.	143 mm.	520 ml.
M Short	62 mm. sq.	118 mm.	420 ml.
N Wide	79 mm. sq.	139 mm.	815 ml.
O Narrow	56 mm. sq.	128 mm.	400 ml.
Rectangular Box:			
P Control	52 x 79 mm.	139 mm.	535 ml.
Q Tall	52 x 79 mm.	152 mm.	580 ml.
R Tall; Narrow Width Base	36 x 63 mm.	143 mm.	370 ml.
S Short; Narrow Width Base	36 x 63 mm.	132 mm.	335 ml.
T Narrow; Narrow Width Base	32 x 56 mm.	128 mm.	215 ml.

TABLE 2
VOLUME REDUCTION CALCULATIONS

Container	Pct. Volume Reduction	Volume Reduction (ml.)	Container	Pct. Volume Reduction	Volume Reduction (ml.)
C-1	35	155	S-1	15	70
C-2	26	115	S-2	39	185
C-3	69	305	S-3	60	280
C-4	62	275	S-4	56	265
C-5	17	75	S-5	50	235
C-6	48	210	S-6	80	375
C-7	53	235	S-7	31	145
C-8	23	100	S-8	53	250
C-9	42	185	S-9	73	345
C-0	55	240	S-0	17	80
E-1	16	45	R-1	21	115
E-2	29	80	R-2	86	460
E-3	45	125	R-3	58	310
E-4	85	235	R-4	68	365
E-5	71	195	R-5	21	110
E-6	60	165	R-6	76	405
E-7	76	210	R-7	34	180
E-8	51	140	R-8	51	275
E-9	67	185	R-9	63	335
E-0	36	100	R-0	43	230

TABLE 3
PHOTOGRAPH COMPOSITION OF NOTEBOOKS

Angular Disparity	Number of Photographs 2	3	4
Low	II*: 0°, 30°	V: 0°, 15°, 30°	VIII: 0°, 10°, 20°, 30°
Moderate	III : 0°, 60°	VI : 0°, 30°, 60°	IX: 0°, 20°, 40°, 60°
High	I : 0°, 90°	IV: 0°, 45°, 90°	VII : 0°, 30°, 60°, 90°

* See text for code.

PROCEDURE

Subjects were tested in groups of nine or less. Their task was comprised of a Pretest, in which their memory for the intact (control) containers was examined, and a Posttest, in which the judgments of volume reduction were made. Upon arriving at the laboratory, the subjects were seated at a table, then read instructions by the experimenter. In brief, the instructions described the purpose of the experiment and stressed the concept of volume reduction. The subjects were told to assume that the half of the container not revealed in the photographs had been damaged to the same extent as the half they could see (this was a legitimate assumption). They were given an opportunity to handle the actual undamaged containers and were urged to study the base dimensions and height of each carefully.

After removing the control containers from view, the experimenter presented each subject with Book 1, the control notebook. Inside the notebook the subject saw photographs of five containers of different dimensions, four each of the four types of objects. Printed instructions required the subject to identify the container whose dimensions were those of the one he had previously handled.

After exchanging Book 1 for Book 2, the notebook containing the photographs of the 40 damaged containers, the subject read printed instructions which reviewed his task and asked him to indicate his judgments of volume reduction to the nearest 5 percent on a rating scale which extended from zero to 100 percent.

Following each day's testing, the data were transferred from the subjects' rating sheets to a special data analysis form to facilitate computations.

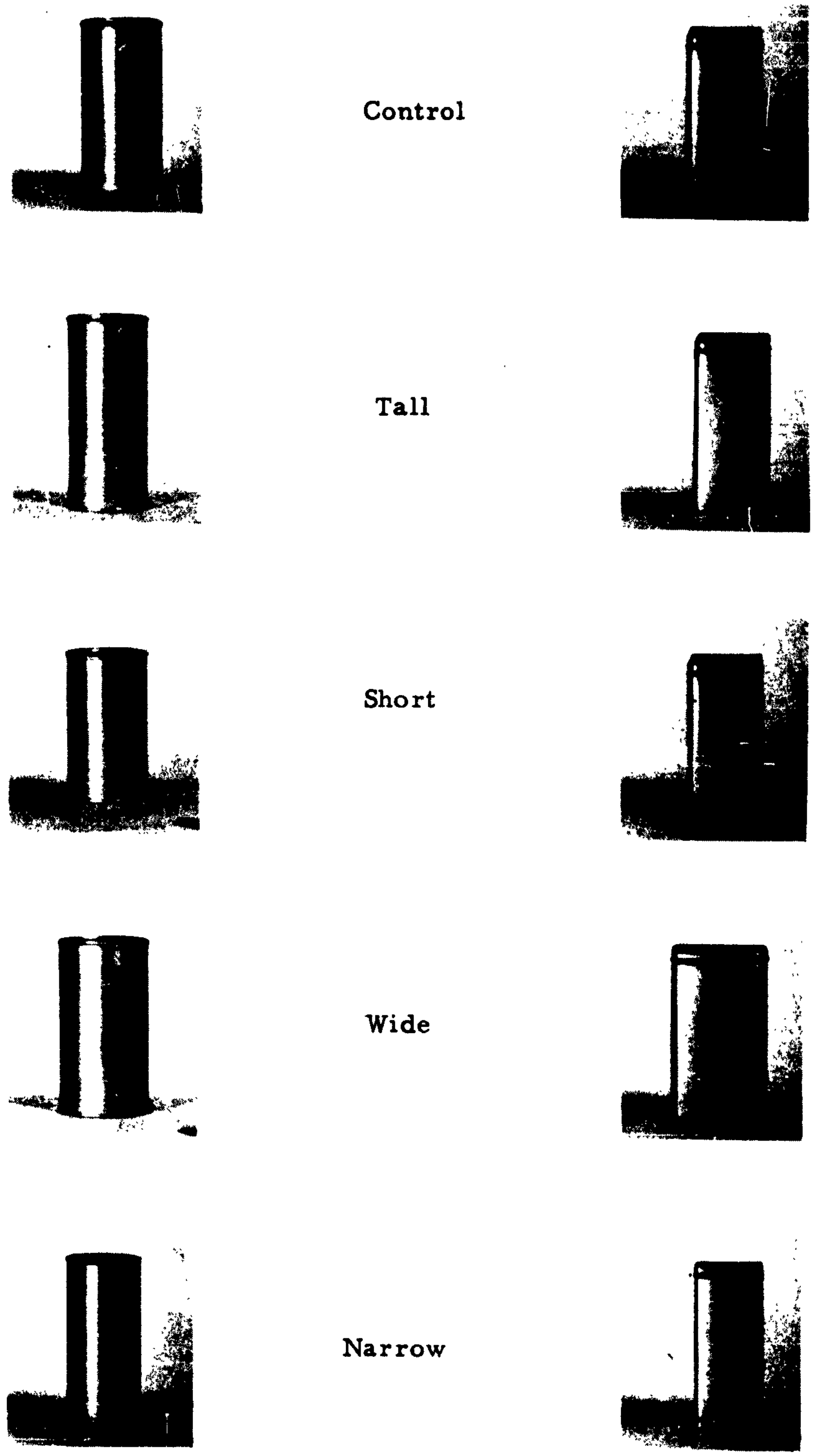

Figure 1. Photographs of Control Containers: Cylinder and Square-Base Box.

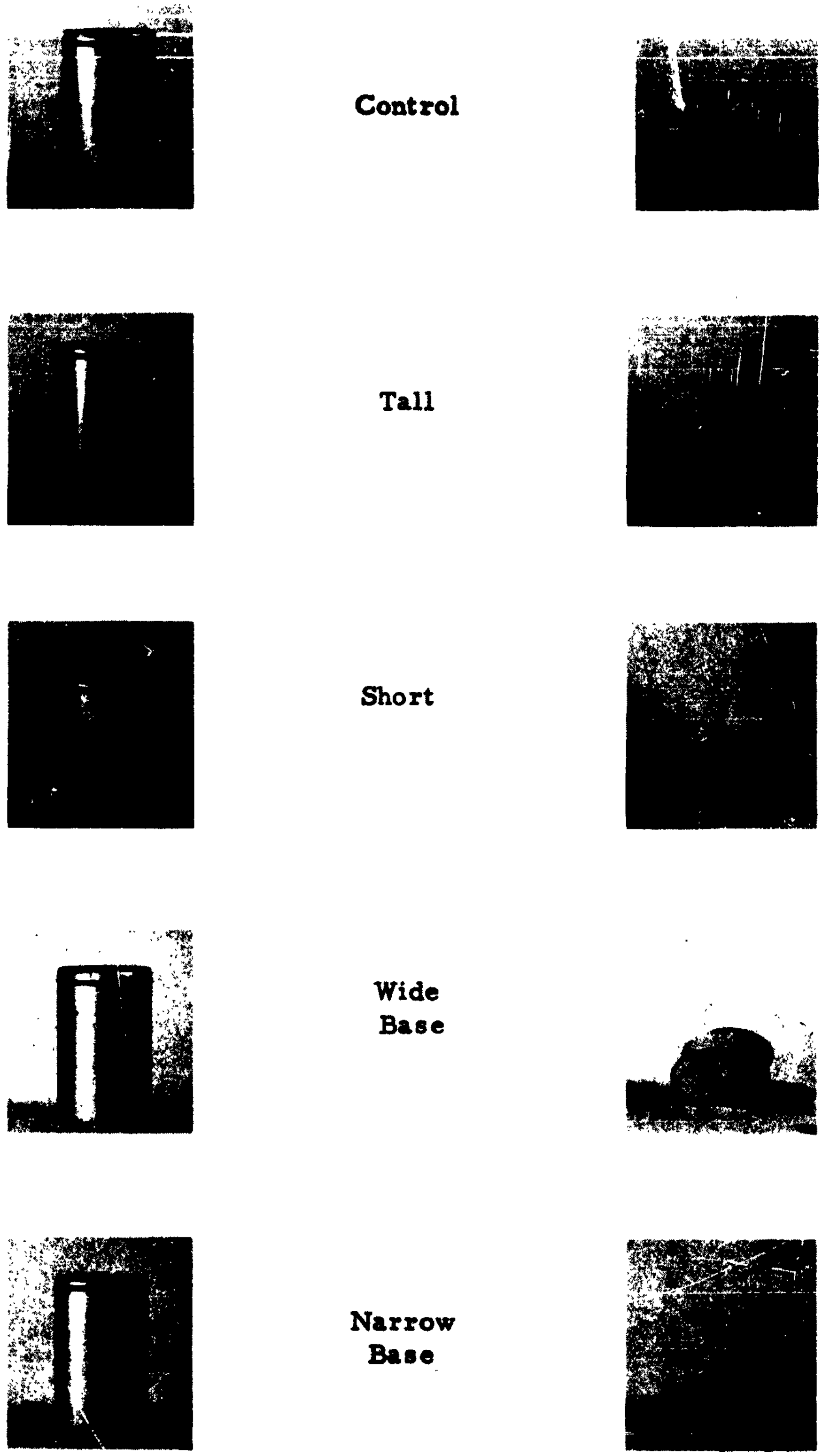

Figure 2. Photographs of Control Containers: Cylindroid.

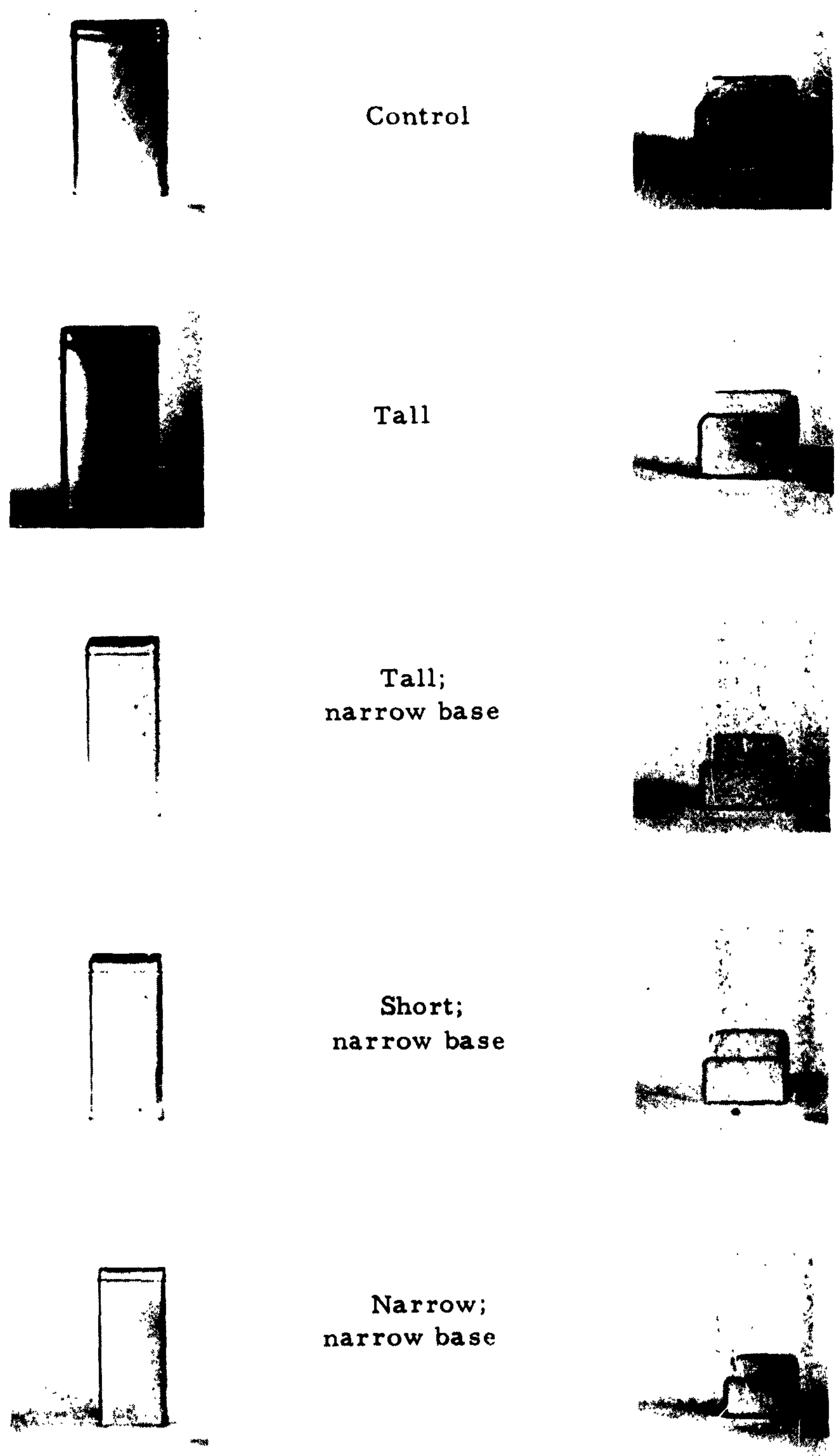

Figure 3. Photographs of Control Containers: Rectangular-Base Box.

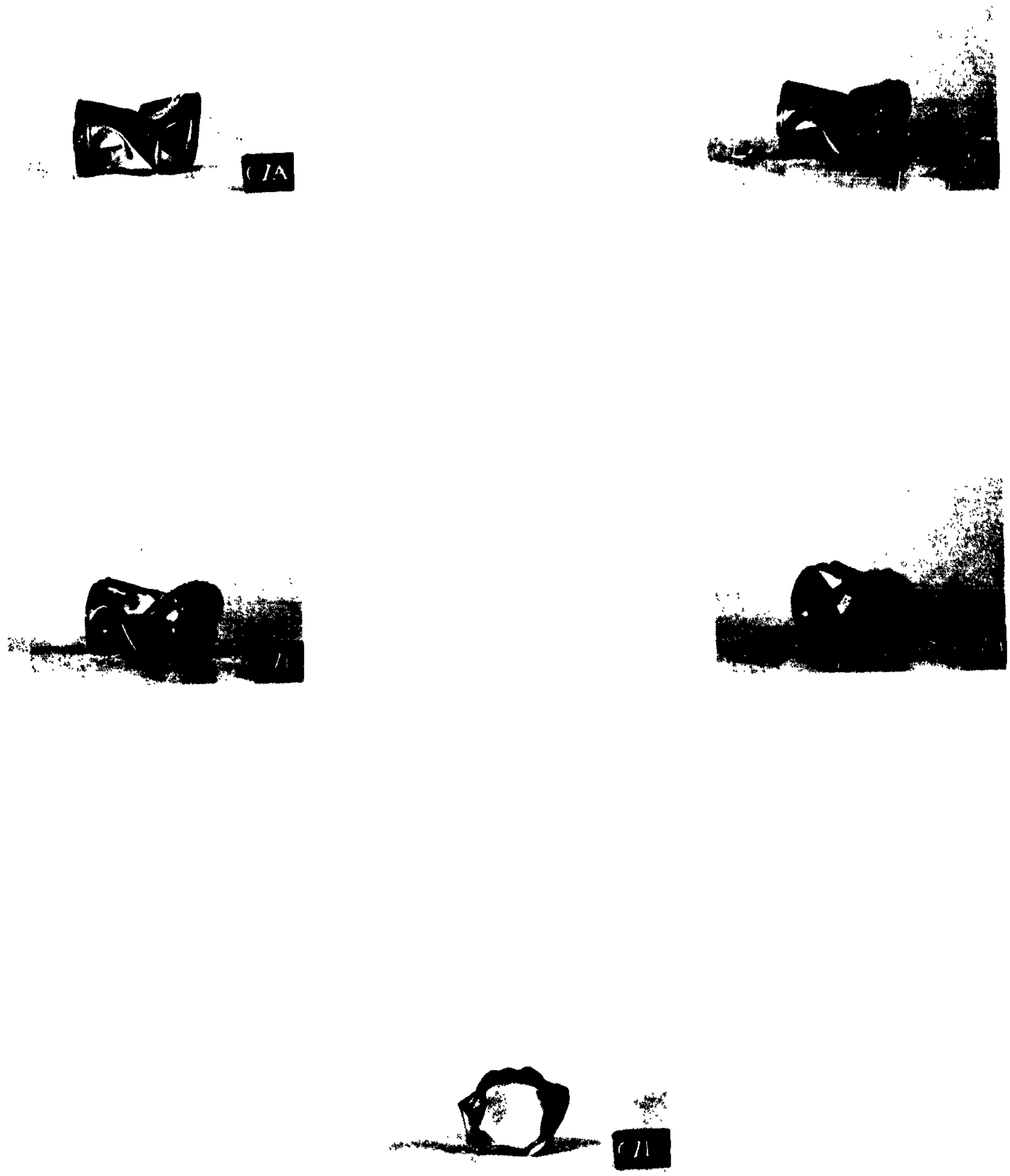

Figure 4. Photographs of Stimulus C-7.

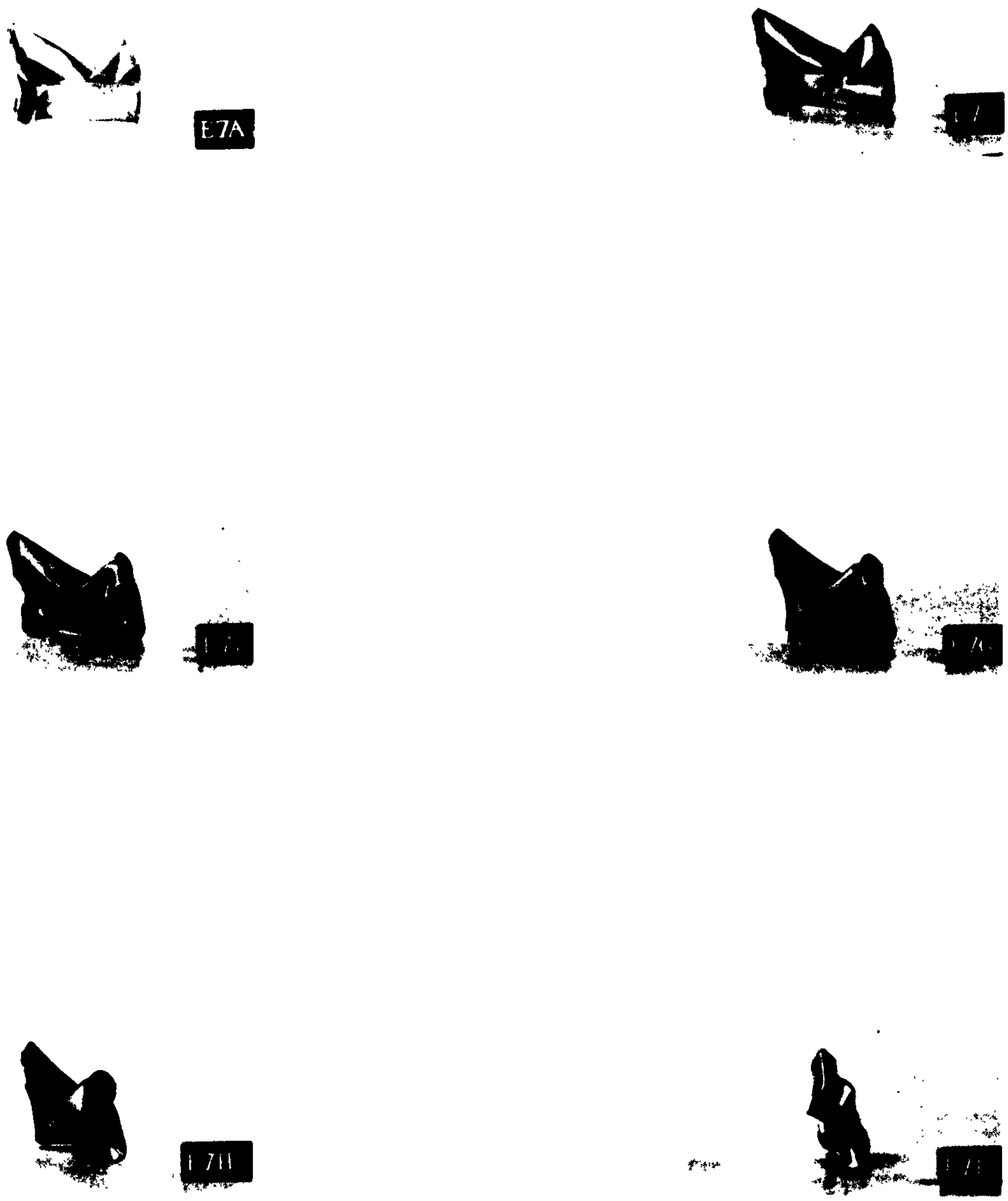

Figure 5. Photographs of Stimulus E-7.

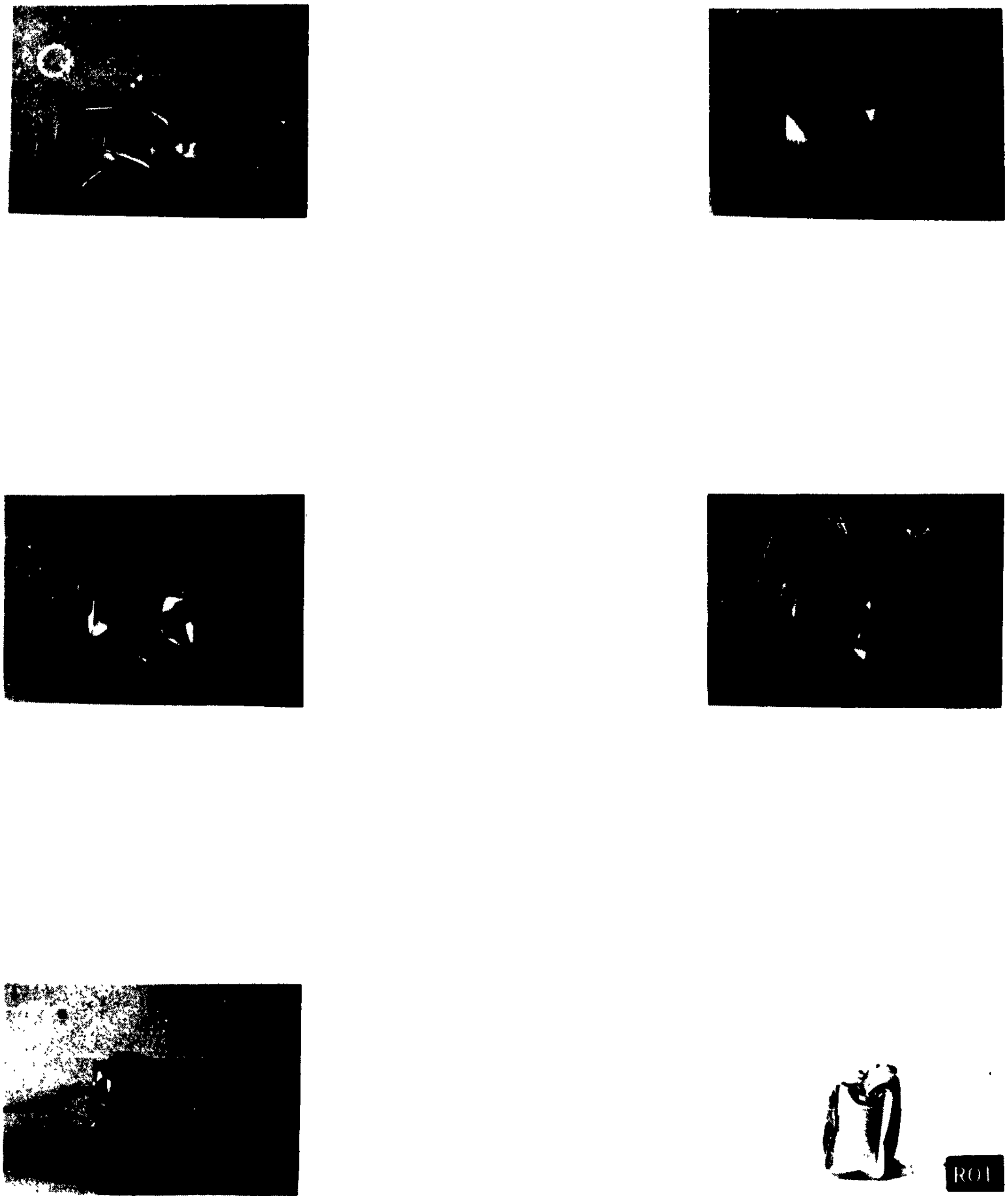

Figure 6. Photographs of Stimulus R-O.

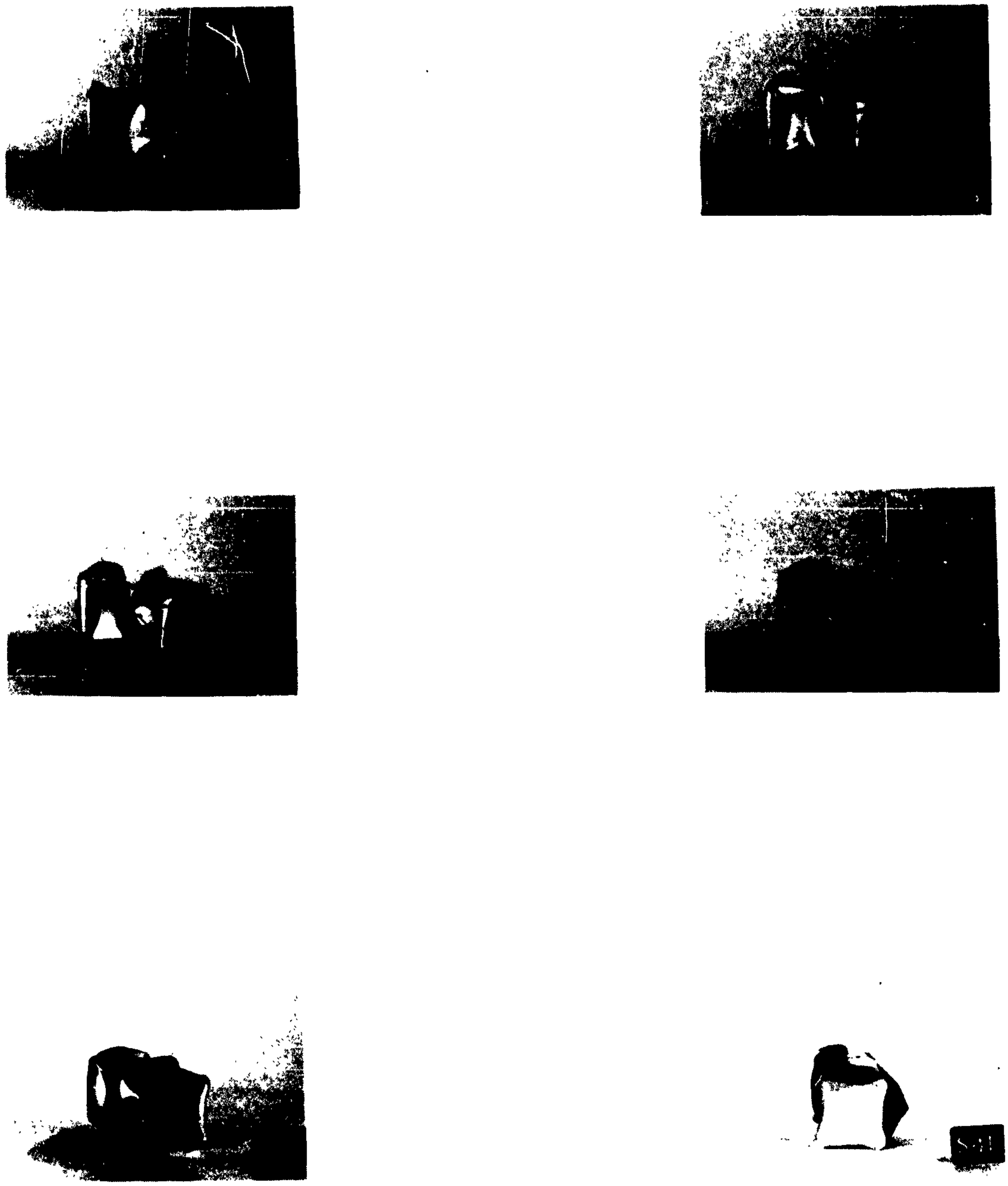

Figure 7. Photographs of Stimulus S-4.

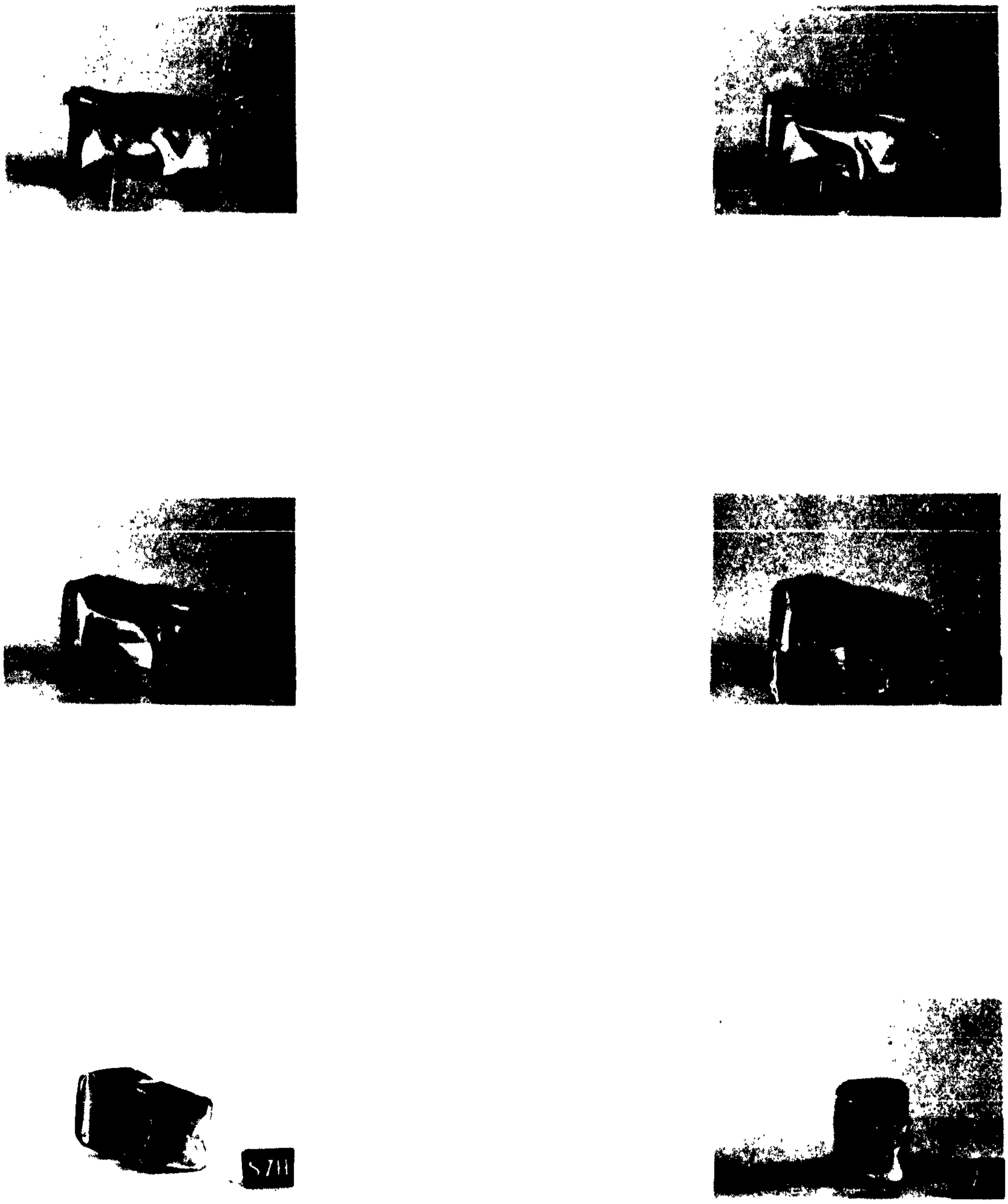

Figure 8. Photographs of Stimulus S-7.

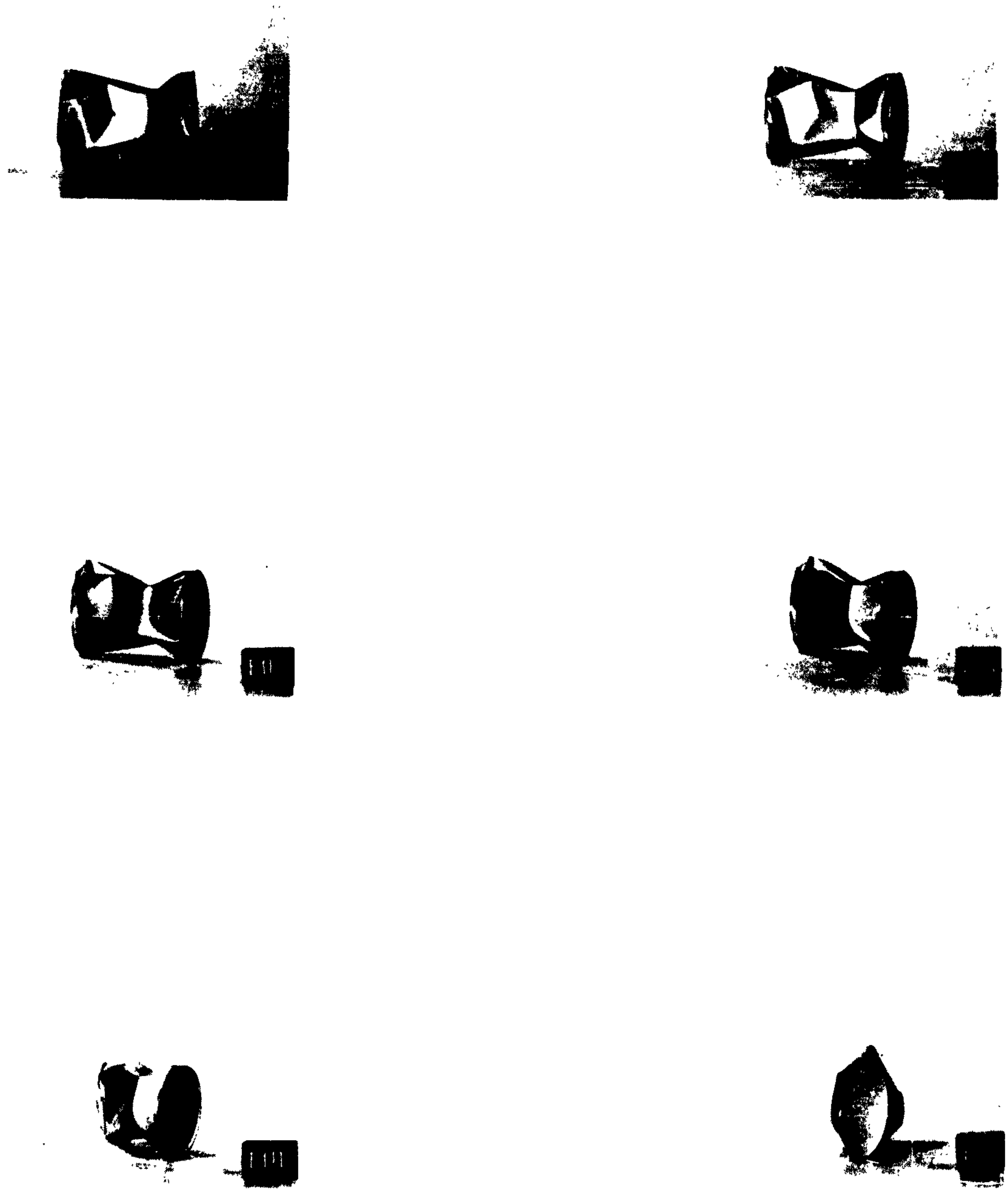

Figure 9. Photographs of Stimulus E-1.

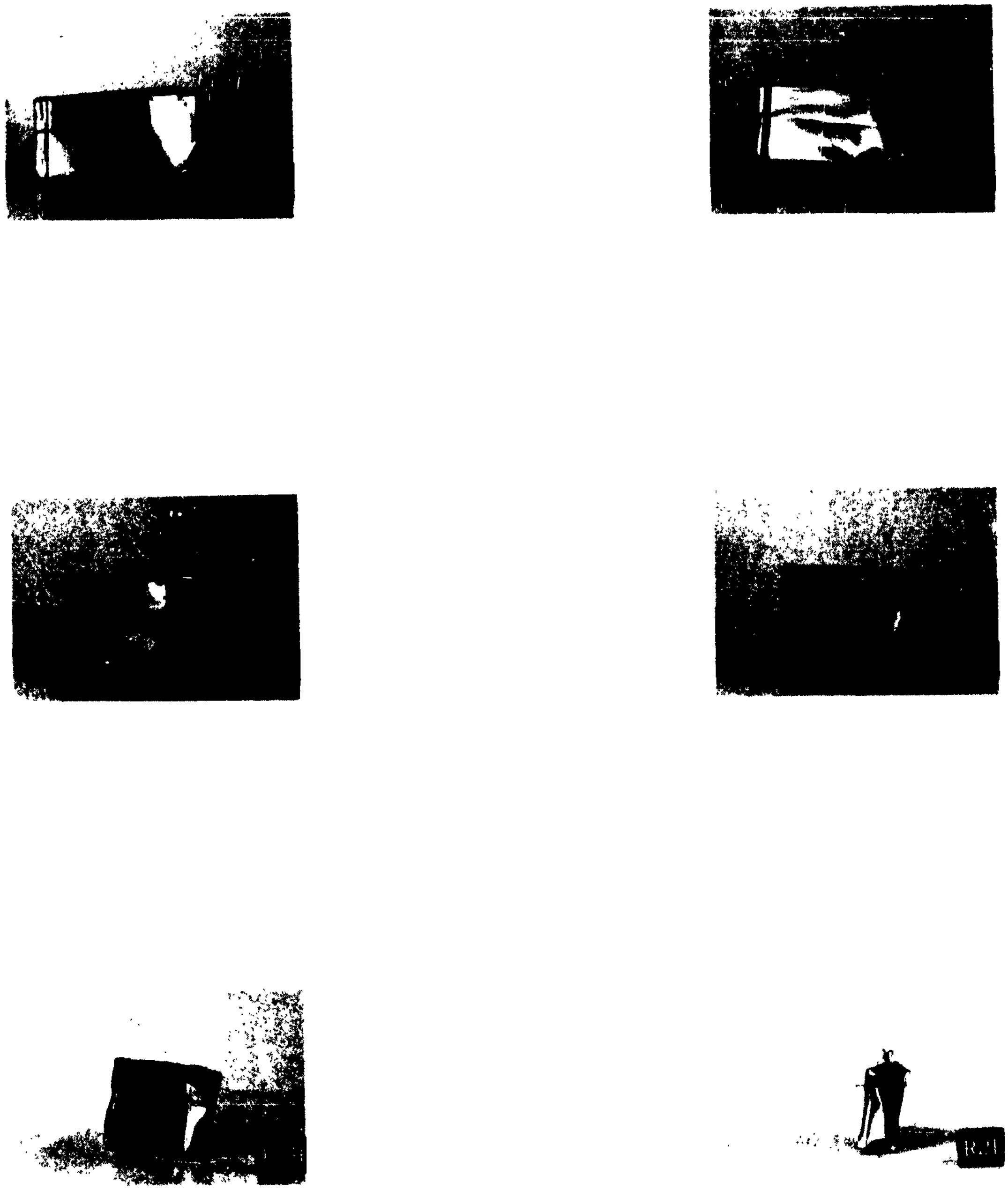

Figure 10. Photographs of Stimulus R-2.

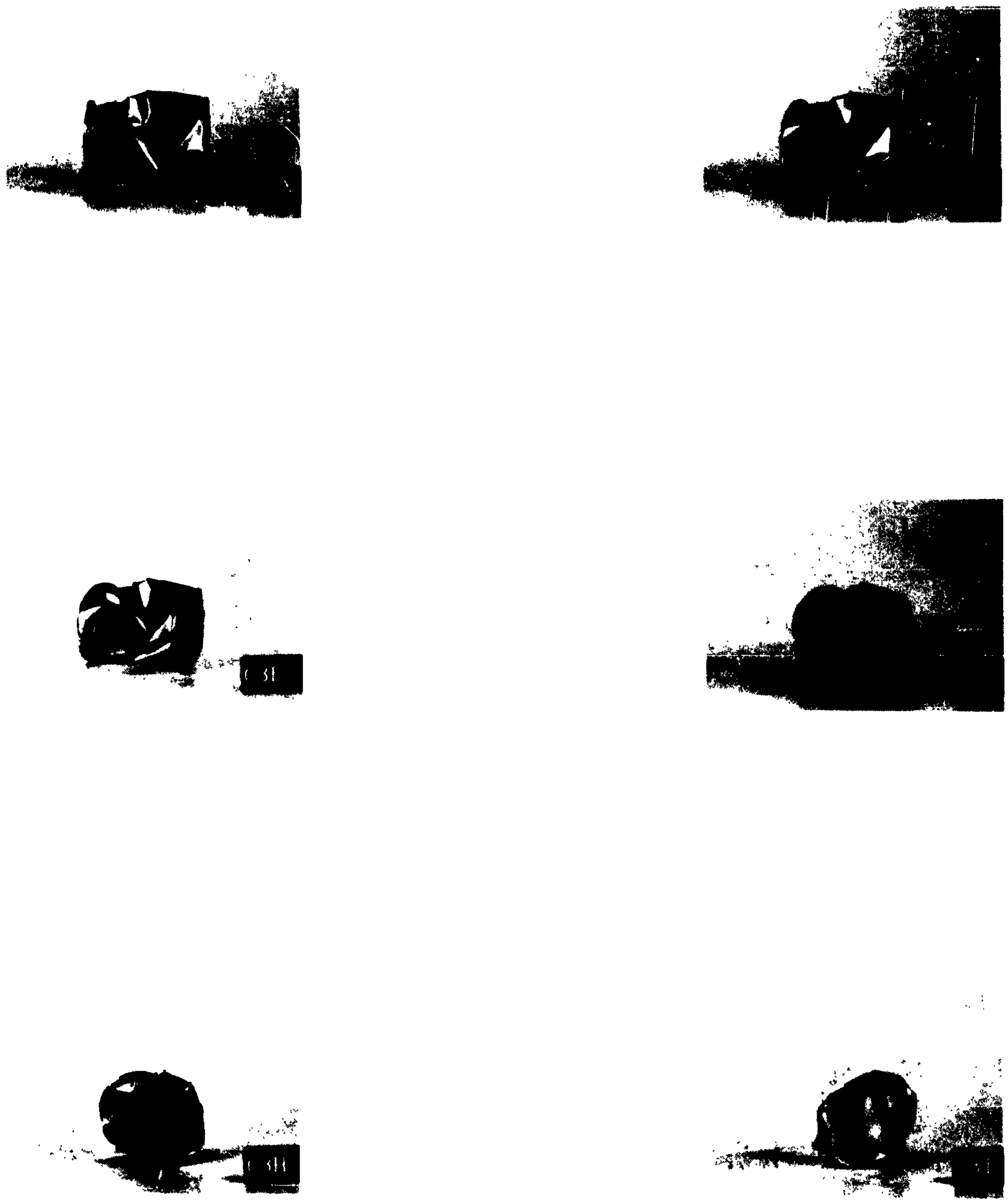

Figure 11. Photographs of Stimulus C-3.

RESULTS

PRETEST RECOGNITION

The purpose of the Pretest was to provide information about the memory process involving the intact (control) objects. In accordance with this objective, the instructions presented by the experimenter deliberately avoided any suggestion of a formal test of retention. Unfortunately, the findings were equivocal. Most subjects verbalized a difficulty in deciding between the various figures and indicated they could only guess as to which one was the control. In support of these remarks, inspection of the data sheets revealed irregular and random responses with no suggestion of clearcut relations to the Posttest data. Table 4 gives the frequency of response to the various containers. The apparent difficulty of the task is further suggested by the fact that only one subject correctly identified all four control containers. The inability of the subjects to make the kinds of discrimination required by the task should, it seems, be attributed to the probability that the subjects were not prepared for the Pretest task rather than be attributed to a question of whether the alternative choices were, in fact, discriminable.

ANALYSIS OF CONSTANT ERRORS AND STANDARD DEVIATIONS

From the raw data (Reference 6), the constant error in judgment (CE), mean judgment (M), and standard deviation (SD) of the judgments about the mean judgment were calculated for each of the 40 stimulus objects at all levels of the independent variables. These values are presented in Table 5. Besides providing a summary of the general characteristics of the data, these statistics leave no doubt that the judgments vary considerably as a function of the stimulus characteristics themselves, apart from type of object. It might have been predicted that the volume reduction of low-damage containers would be overestimated and that the volume reduction of high-damage containers would be underestimated, but this does not necessarily follow. Stimulus E-7 (Figure 5) has a volume reduction of 76 percent yet is consistently overestimated, while S-7 (Figure 8) with a volume reduction of 31 percent is consistently underestimated. Stimulus R-O (Figure 6) is underestimated while S-4 (Figure 7) and E-1 (Figure 9) are overestimated. It is possible that those stimuli which retain their original longitudinal dimensions are underestimated while those whose longitudinal dimensions are distorted are overestimated. Particular note should be made here of Stimulus R-2. At low and moderate angular

TABLE 4
RESULTS OF THE PRETEST

Container		Frequency of Response
Cylinder:		
A	Control	110
B	Tall	15
C	Short	36
D	Wide	57
E	Narrow	61
Cylindroid:		
F	Control	27
G	Tall	25
H	Short	15
I	Wide Base	4
J	Narrow Base	208
Square-Box:		
K	Control	112
L	Tall	29
M	Short	84
N	Wide	8
O	Narrow	46
Rectangular-Box:		
P	Control	106
Q	Tall	75
R	Tall; Narrow Width Base	26
S	Short; Narrow Width Base	49
T	Narrow; Narrow Width Base	23

TABLE 5

GENERAL DATA CHARACTERISTICS: THE MEAN, STANDARD DEVIATION, AND CONSTANT ERROR OF THE JUDGMENTS OF EACH STIMULUS--

A. FOR THE TWO-PHOTOGRAPH SUBGROUP

Container	Pct. Volume Reduction	Angular Disparity: Low CE	Low M	Low SD	Moderate CE	Moderate M	Moderate SD	High CE	High M	High SD
C-1	35	2.9	37.9	16.7	10.3	45.3	16.9	9.4	44.4	16.2
C-2	26	9.6	35.6	16.4	15.5	41.5	18.5	4.2	30.2	15.8
C-3	69	1.6	70.6	16.4	1.3	70.3	14.5	2.9	71.9	16.8
C-4	62	7.2	69.2	17.5	15.7	77.7	14.1	8.6	70.6	20.3
C-5	17	13.8	30.8	11.0	15.4	32.4	9.1	14.3	31.3	15.7
C-6	48	13.0	61.0	18.3	16.4	64.4	17.2	20.1	68.1	15.8
C-7	53	24.1	77.1	11.8	23.8	76.8	12.5	16.8	69.8	14.2
C-8	23	8.5	31.5	18.8	13.0	36.0	19.9	38.3	61.3	20.8
C-9	42	4.3	46.3	15.4	17.0	59.0	18.4	9.5	51.5	18.2
C-10	55	14.5	69.5	14.3	23.5	78.5	11.2	15.0	70.0	14.9
Means	43.0		53.0			58.2			56.9	
E-1	16	37.2	53.2	15.3	30.9	46.9	15.3	36.1	52.1	19.6
E-2	29	12.9	41.9	18.5	30.2	59.2	18.0	28.9	57.9	17.8
E-3	45	22.6	67.6	15.2	23.9	68.9	15.0	15.2	60.2	19.8
E-4	85	-13.4	71.6	24.4	0.5	85.5	11.7	5.8	90.8	6.7
E-5	71	- 8.7	62.3	22.2	7.4	78.4	14.6	5.6	76.6	17.5
E-6	60	-16.3	43.7	20.1	-12.6	47.4	19.5	-1.3	58.7	24.8
E-7	76	2.5	78.5	11.2	9.2	85.2	9.5	10.3	86.3	9.8
E-8	51	3.7	54.7	21.9	20.3	71.3	20.1	13.7	64.7	21.4
E-9	67	-5.4	61.6	15.4	-0.2	66.8	15.4	6.5	73.5	16.4
E-10	36	-9.1	26.9	17.3	-5.5	30.5	17.2	-8.6	27.4	13.7
Means	53.6		56.2			64.0			64.8	

TABLE 5 (Cont'd.)

GENERAL DATA CHARACTERISTICS: THE MEAN, STANDARD DEVIATION, AND CONSTANT ERROR OF THE JUDGMENTS OF EACH STIMULUS--

A. FOR THE TWO-PHOTOGRAPH SUBGROUPS

Con-tainer	Pct. Volume Reduction	Angular Disparity: Low CE	Low M	Low SD	Moderate CE	Moderate M	Moderate SD	High CE	High M	High SD
R-1	21	-1.0	20.0	13.9	-0.4	20.6	11.5	2.4	23.4	17.7
R-2	86	-35.0	51.0	24.4	-23.4	62.6	20.4	-0.4	85.6	10.9
R-3	58	- 9.0	49.0	21.6	7.3	65.3	14.4	8.8	66.8	17.3
R-4	68	-19.9	48.1	16.7	-6.1	61.9	16.2	-23.5	44.5	15.5
R-5	21	5.3	26.3	15.7	2.7	23.7	9.5	1.7	22.7	10.3
R-6	76	-10.7	65.3	16.8	-4.7	71.3	18.0	-11.5	64.5	15.1
R-7	34	11.3	45.3	15.7	11.0	45.0	12.9	0.2	34.2	17.9
R-8	51	-4.4	46.6	16.3	6.4	57.4	12.2	4.6	55.6	21.4
R-9	63	5.1	68.1	17.4	8.9	71.9	13.4	3.3	66.3	16.7
R-10	43	0.5	43.5	16.0	-5.4	37.6	12.2	-18.0	25.0	16.4
Means	52.1		46.3			51.7			48.9	
S-1	15	9.8	24.8	14.7	16.8	31.8	14.9	11.6	26.6	17.3
S-2	39	-3.4	35.6	15.5	-3.4	35.6	13.5	1.3	40.3	19.3
S-3	60	1.3	61.3	14.6	15.6	75.6	12.4	4.5	64.5	16.6
S-4	56	18.2	74.2	15.7	21.1	77.1	7.7	11.7	67.7	14.9
S-5	50	9.4	59.4	20.4	11.0	61.0	18.2	7.1	57.1	19.7
S-6	80	0.3	80.3	12.9	1.9	81.9	12.0	-5.5	74.5	15.3
S-7	31	-11.8	19.2	14.6	-11.6	19.4	9.4	-7.5	23.5	14.5
S-8	53	2.0	55.0	17.3	0.9	53.9	16.4	-1.7	51.3	20.7
S-9	73	-13.2	59.8	16.1	-10.1	62.9	18.8	-21.6	51.4	19.2
S-10	17	12.0	29.0	11.2	12.4	29.4	9.5	13.3	30.3	14.7
Means	47.4		49.9			52.9			48.7	

TABLE 5 (Cont'd.)

GENERAL DATA CHARACTERISTICS: THE MEAN, STANDARD DEVIATION, AND CONSTANT ERROR OF THE JUDGMENTS OF EACH STIMULUS--

B. FOR THE THREE-PHOTOGRAPH SUBGROUP

Container	Pct. Volume Reduction	Angular Disparity Low CE	M	SD	Moderate CE	M	SD	High CE	M	SD
C-1	35	-1.6	33.4	15.4	5.6	40.6	11.1	6.8	41.8	14.9
C-2	26	4.2	30.2	15.7	8.0	34.0	14.1	3.8	29.8	18.2
C-3	69	-6.4	62.6	14.8	2.0	71.0	14.8	-3.4	65.6	15.2
C-4	62	4.9	66.9	17.4	10.6	72.6	13.6	2.2	64.2	17.5
C-5	17	10.6	27.6	6.9	14.9	31.9	13.4	10.1	27.1	10.3
C-6	48	6.7	54.7	18.7	10.1	58.1	15.2	6.8	54.8	17.1
C-7	53	19.1	72.1	14.4	19.4	72.4	12.6	17.0	70.0	14.2
C-8	23	4.6	27.6	14.4	12.8	35.8	21.9	19.4	42.4	19.0
C-9	42	3.8	45.8	13.4	6.2	48.2	17.0	4.8	46.8	15.6
C-10	55	9.7	64.7	18.5	13.7	68.7	15.5	8.1	63.1	18.8
Means	43.0		48.6			53.3			50.6	
E-1	16	30.8	46.8	15.9	31.1	47.1	15.2	34.5	50.5	15.7
E-2	29	15.4	44.4	16.9	17.1	46.1	14.1	21.2	50.2	20.1
E-3	45	14.8	59.8	17.0	15.0	60.0	15.4	13.5	58.5	15.0
E-4	85	-14.5	70.5	23.7	0.5	85.5	11.8	-2.7	82.3	14.2
E-5	71	- 7.5	63.5	20.6	5.1	76.1	14.5	9.5	80.5	12.1
E-6	60	-19.4	40.6	18.4	-16.1	43.9	18.8	-13.2	46.8	19.9
E-7	76	0.0	76.0	14.9	10.8	86.8	7.4	4.3	80.3	17.1
E-8	51	0.5	51.5	20.9	14.8	65.8	19.5	15.1	66.1	15.7
E-9	67	-10.9	56.1	23.5	-6.8	60.2	18.3	-2.8	64.2	16.9
E-10	36	-12.5	23.5	14.3	-4.5	31.5	17.4	-3.7	32.3	15.0
Means	53.6		53.3			60.3			61.2	

TABLE 5 (Cont'd.)

GENERAL DATA CHARACTERISTICS: THE MEAN, STANDARD DEVIATION, AND CONSTANT ERROR OF THE JUDGMENTS OF EACH STIMULUS--

B. FOR THE THREE-PHOTOGRAPH SUBGROUP

Con-	Pct.	Angular Disparity								
	Volume	Low			Moderate			High		
tainer	Reduction	CE	M	SD	CE	M	SD	CE	M	SD
R-1	21	-0.8	20.2	9.7	-4.7	16.3	8.3	-4.7	16.3	8.0
R-2	86	-31.3	54.7	25.3	-25.8	60.2	2[illegible].9	-5.2	80.8	12.7
R-3	58	-12.5	45.5	15.0	3.3	61.3	14.8	0.1	58.1	18.0
R-4	68	-20.4	47.6	17.1	-11.5	56.5	13.9	-28.0	40.0	11.1
R-5	21	4.5	25.5	8.4	4.0	25.0	11.6	2.5	23.5	15.1
R-6	76	-10.0	66.0	15.4	-10.5	65.5	16.1	-18.6	57.4	16.5
R-7	34	3.7	37.7	13.0	4.1	38.1	11.8	2.3	36.3	12.5
R-8	51	-5.4	45.6	15.8	2.5	53.5	15.8	-6.2	44.8	16.2
R-9	63	5.2	68.2	19.7	6.5	69.5	14.6	0.4	63.4	14.5
R-10	43	-7.8	35.2	14.3	-7.8	35.2	9.9	-9.0	34.0	14.6
Means	52.1		44.6			48.1			45.5	
S-1	15	10.6	25.6	15.0	12.3	27.3	12.8	16.1	31.1	18.0
S-2	39	-6.6	32.4	18.6	-6.3	32.7	19.4	-1.1	37.9	16.1
S-3	60	-5.6	54.4	16.0	3.1	63.1	13.9	-7.4	52.6	13.1
S-4	56	18.2	74.2	13.4	19.5	75.5	16.2	16.1	72.1	12.0
S-5	50	-4.4	45.6	20.4	-0.6	49.4	19.6	-0.8	49.2	20.8
S-6	80	-2.1	77.9	14.3	-2.3	77.7	12.6	-9.0	71.0	14.1
S-7	31	-8.6	22.4	14.0	-11.0	20.0	7.6	-10.4	20.6	11.4
S-8	53	-6.7	46.3	15.7	3.0	56.0	16.2	-7.2	45.8	12.4
S-9	73	-16.4	56.6	17.0	-6.4	66.6	12.1	-14.8	58.2	14.4
S-10	17	10.4	27.4	11.6	10.1	27.1	8.6	10.1	27.1	10.5
Means	47.4		46.3			49.6			46.6	

TABLE 5 (Cont'd.)
GENERAL DATA CHARACTERISTICS: THE MEAN, STANDARD DEVIATION, AND CONSTANT ERROR OF THE JUDGMENTS OF EACH STIMULUS--
C. FOR THE FOUR-PHOTOGRAPH SUBGROUP

Container	Pct. Volume Reduction	Angular Disparity								
		Low			Moderate			High		
		CE	M	SD	CE	M	SD	CE	M	SD
C-1	35	3.9	38.9	14.4	6.9	41.9	16.5	2.4	37.4	17.0
C-2	26	6.4	32.4	12.0	8.2	34.2	20.0	11.6	37.6	17.0
C-3	69	-6.6	62.4	15.5	-3.0	66.0	17.7	1.5	70.5	17.7
C-4	62	10.3	72.3	16.2	8.0	70.0	13.3	5.6	67.6	18.2
C-5	17	15.6	32.6	11.5	14.3	31.3	12.8	12.5	29.5	14.6
C-6	48	2.6	50.6	17.2	7.2	55.2	14.8	9.3	57.3	17.9
C-7	53	21.4	74.4	11.8	21.4	74.4	14.5	17.2	70.2	15.6
C-8	23	8.1	31.1	16.8	3.8	26.8	20.0	12.0	35.0	20.4
C-9	42	5.6	47.6	16.2	8.3	50.3	13.1	10.4	52.4	18.0
C-10	55	14.4	69.4	15.6	16.5	71.5	16.3	14.7	69.7	13.8
Means	43.0		51.2			52.2			52.7	
E-1	16	30.6	46.6	14.9	27.2	43.2	16.8	29.2	45.2	15.8
E-2	29	11.5	40.5	15.4	16.8	45.8	17.9	19.5	48.5	15.4
E-3	45	22.3	67.3	11.5	17.1	62.1	14.7	13.7	58.7	15.2
E-4	85	-5.6	79.4	16.4	-2.6	82.4	13.1	-0.5	84.5	11.7
E-5	71	-4.2	66.8	16.2	3.4	74.4	13.4	11.7	82.7	12.5
E-6	60	-16.5	43.5	18.2	-19.7	40.3	18.0	-14.0	46.0	18.0
E-7	76	2.7	78.7	11.0	7.9	83.9	10.0	7.1	83.1	13.9
E-8	51	0.3	51.3	17.5	11.1	62.1	20.4	15.9	66.9	15.3
E-9	67	-14.7	52.3	19.7	-1.8	65.2	15.6	-1.8	65.2	15.9
E-10	36	-9.5	26.5	12.3	-9.5	26.5	18.2	-8.4	27.6	16.3
Means	53.6		55.3			58.6			60.7	

TABLE 5 (Cont'd.)

GENERAL DATA CHARACTERISTICS: THE MEAN, STANDARD DEVIATION, AND CONSTANT ERROR OF THE JUDGMENTS OF EACH STIMULUS--

C. FOR THE FOUR-PHOTOGRAPH SUBGROUP

Container	Pct. Volume Reduction	Angular Disparity: Low CE	Low M	Low SD	Moderate CE	Moderate M	Moderate SD	High CE	High M	High SD
R-1	21	-0.8	20.2	10.4	-3.7	17.3	14.1	-2.3	18.7	15.8
R-2	86	-25.0	61.0	24.3	-32.0	54.0	24.7	-6.0	80.0	13.9
R-3	58	-9.9	48.1	17.8	0.1	58.1	17.1	0.5	58.5	16.6
R-4	68	-21.5	46.5	17.3	-19.3	48.7	17.1	-17.5	50.5	17.5
R-5	21	5.8	26.8	13.3	3.2	24.2	11.6	4.6	25.6	14.8
R-6	76	-11.8	64.2	12.1	-7.9	68.1	13.6	-10.2	65.8	13.7
R-7	34	8.6	42.6	12.6	4.7	38.7	12.5	-0.9	33.1	15.3
R-8	51	-2.1	48.9	16.6	0.3	51.3	16.3	-5.0	46.0	18.9
R-9	63	8.6	71.6	12.6	-0.4	62.6	16.2	2.3	65.3	14.3
R-10	43	-3.8	39.2	17.3	-8.3	34.7	15.3	-10.9	32.1	15.7
Means	52.1		46.9			45.8			47.6	
S-1	15	14.0	29.0	15.0	12.6	27.6	15.3	11.1	26.1	15.5
S-2	39	-3.7	35.3	17.3	-6.3	32.7	13.6	-4.2	34.8	16.6
S-3	60	-0.6	59.4	16.9	3.9	63.9	13.5	1.6	61.6	16.6
S-4	56	20.5	76.5	12.6	19.3	75.3	14.5	14.6	70.6	14.5
S-5	50	3.5	53.5	21.0	0.8	50.8	17.6	3.9	53.9	17.1
S-6	80	0.2	80.2	10.5	-0.5	79.5	11.2	-2.1	77.9	16.6
S-7	31	-9.4	21.6	10.6	-15.5	15.5	8.2	-12.0	19.0	12.3
S-8	53	-2.5	50.5	14.9	-1.4	51.6	13.8	-0.7	52.3	18.0
S-9	73	-20.6	52.4	17.2	-13.5	59.5	19.1	-18.0	55.0	17.8
S-10	17	10.3	27.3	9.1	13.0	30.0	10.2	8.6	25.6	10.1
Means	47.4		48.6			48.6			47.7	

disparity, where the integrity of the longitudinal axis is seen in Figure 10 to be maintained, the data showed extremely large errors of underestimation; whereas at high angular disparity, the unique features of this container are revealed, and judgments become quite accurate. Here is a case where angular disparity is an important variable determining accuracy of judgment. It is interesting to note that other stimuli (E-7, R-O) are judged more accurately at lower angular disparities. Finally, there are stimuli like C-3 (Figure 11) that are judged accurately at all angular disparities where two photographs give as accurate a judgment as do three or four, whereas Stimulus C-7 (Figure 4) has a large constant error under all experimental conditions.

Another way of looking at Table 5 is to consider each of the 40 individual stimuli as separate units of analysis. Since an effort was made to achieve comparable kinds and levels of damage from one type of object to another, the question logically arises as to whether, in fact, the subjects' responses were influenced by the type of object. The alternative view is that the way the containers were damaged yielded some particularly unique stimuli which then principally determine the mean constant errors for the individual types of objects. To resolve the issue, separate analyses of variance were performed upon the standard deviations and constant errors (with a constant value of 40 added to eliminate negative figures). As seen in Tables 6 and 7, the sums of squares for the variable stimuli were partitioned into two terms, one involving objects and one involving stimuli within objects, with the mean square of the latter then being used as the error term to test the significance of the former. This test revealed significant differences in the constant errors for objects but not for the standard deviations. Table 8 presents the means of the constant errors and standard deviations for the four types of objects. Clearly, type of object can be identified as a significant source of variance. Since the dispersion of responses for each type of object was comparable, their variances are homogeneous, and thus an overall analysis of variance of the main effects of number of photographs, angular disparity, and type of object is possible.

ANALYSIS OF AVERAGE ERRORS

Hypotheses H:1 and H:2 reflect the principal interest of this study in the accuracy of observers' judgments. The data chosen for the analysis basic to the test of these hypotheses were the average errors derived from the absolute deviations of the obtained judgments from the known volume reduction. The frequency distributions of the average errors for each of the nine subgroups were found to be comparable in terms

TABLE 6
ANALYSIS OF VARIANCE OF CONSTANT ERRORS

Source	df	SS	MS	F	P
Number of Photographs (N)	2	898.81	449.40	7.18	05
Angular Disparity (A)	2	836.99	418.50	6.69	n.s.
N x A	4	250.38	62.60	45.69	.001
Stimuli (S)	(39)	(45520.22)	1167.19		
Objects (O)	3	10823.59	3607.86	3.74	.025
Stimuli within (Sw)	36	34696.63	963.80		
A x S	(78)	(4351.26)	55.79		
A x D	6	518.52	86.42	1.62	n.s.
A x Sw	72	3832.74	53.23		
N x S	(78)	(921.97)	11.82		
N x O	6	66.21	11.04	0.93	n.s.
N x Sw	72	855.76	11.89		
A x N x S	(156)	(1355.19)	8.69		
A x N x O	12	46.57	3.88	0.43	n.s.
A x N x Sw	144	1308.62	9.09		
Total	359	54134.82			

TABLE 7
ANALYSIS OF VARIANCE OF STANDARD DEVIATIONS

Source	df	SS	MS	F	P
Number of Photographs (N)	2	39.80	19.90	0.97	n.s.
Angular Disparity (A)	2	91.65	45.82	2.22	n.s.
N x A	4	82.42	20.60	5.60	.001
Stimuli (S)	(39)	(1854.87)	47.56		
Objects (O)	3	105.56	35.19	0.72	n.s.
Stimuli within (Sw)	36	1749.31	48.59		
A x S	(78)	(865.98)	11.10		
A x O	6	97.82	16.30	1.53	n.s.
A x Sw	72	768.16	10.67		
N x S	(78)	(401.82)	5.15		
N x O	6	57.41	9.57	2.00	n.s.
N x Sw	72	344.41	4.78		
A x N x S	(156)	(570.75)	3.66		
A x N x O	12	40.44	3.37	0.92	n.s.
A x N x Sw	144	530.31	3.68		
Total	359	3907.29			

TABLE 8

MEANS OF THE CONSTANT ERRORS AND STANDARD DEVIATIONS

	Type of Object			
	C	E	R	S
Constant Error	10.0	5.8	- 4.8	1.3
Standard Deviation	15.7	16.3	15.3	14.8

of both form and variance, and were neither markedly flat nor peaked. Consequently, in terms of the Norton study (Reference 5, page 78), the use of analysis of variance techniques was not precluded. To determine the statistical significance of the independent variables, a "Type VI" analysis of variance (Reference 5, page 296), as shown in Table 9, was performed on the data. In this approach, the sums of squares are partitioned so that subject differences are controlled over two main "within" effects: objects (the four types of containers) and damage. For this analysis, the latter variable was defined at two levels, low damage and high damage, by dividing the 10 containers of each object type into groups of 5 each according to their volume reduction.

Of the two independent variables, only the number of photographs constituted a significant source of variance. From Table 10, which gives the overall average errors for the main effects and their interactions, it is apparent that this finding can be attributed to the reduction in error of judgment when a third photograph is added to a pair. Adding a fourth photograph does not lead to greater judgmental proficiency.

The role of stimulus characteristics is again emphasized by the significant F ratios obtained for objects and the O x D interaction. The average errors for these sources of variance are given in Table 11. It is evident that judgments of volume reduction of the cylinder are considerably less accurate than those for either the rectangular box or the square box, while those for the cylindroid are even more in error. The O x D interaction evidently can be attributed to the cylindroid means which reverse a general (though nonsignificant) trend in which judgments of high-damage objects are accompanied by higher errors than those of low-damage objects.

The mean average errors for objects (Table 11) suggest a basis for classifying the types of containers according to independent measures

TABLE 9

ANALYSIS OF VARIANCE OF AVERAGE ERRORS

Source	df	SS	MS	F	P
Between Subjects	(278)	(26559.15)			
1. Angular Disparity (A)	2	63.89	31.94	--	
2. Number of Photographs (N)	2	1156.63	578.32	6.21	.005
3. N x A	4	179.44	44.86	--	
4. Error (b)	270	25159.19	93.18		
Within Subjects	(1953)	(84412.92)			
5. Objects (O)	3	4380.25	1460.08	43.61	.001
a. Roundness-Squareness	(1)	3356.26	3356.26	100.25	.001
b. Base Symmetry	(1)	540.34	540.34	16.14	.001
c. Interaction	(1)	483.65	483.65	14.45	.001
6. Damage (D)	1	114.26	114.26	2.18	n. s.
7. O x D	3	11928.90	3976.30	143.19	.001
8. N x O	6	501.40	83.57	2.50	.05
9. N x D	2	288.00	144.00	2.75	n. s.
10. A x O	6	739.08	123.18	3.68	.01
11. A x D	2	1023.59	511.80	9.77	.01
12. N x O x D	6	399.91	66.65	2.40	.05
13. A x O x D	6	622.02	103.67	3.73	.01
14. N x A x O	12	320.01	26.67	--	
15. N x A x D	4	152.47	38.12	--	
16. N x A x O x D	12	187.16	15.60	--	
17. Error W-1	810	27119.24	33.48		
18. Error W-2	270	14141.35	52.38		
19. Error W-3	810	22495.28	27.77		
	2231	110972.07			

TABLE 10
AVERAGE ERRORS FOR THE VARIABLES, ANGULAR DISPARITY, AND NUMBER OF PHOTOGRAPHS

Angular Disparity	Number of Photographs 2	3	4	Means
Low	16.76	16.00	15.55	16.10
Moderate	16.70	14.98	15.55	15.74
High	17.54	15.33	15.42	16.10
Means	17.00	15.44	15.51	15.98

TABLE 11
AVERAGE ERRORS FOR THE VARIABLES: DAMAGE AND OBJECTS

Damage	Type of Object C	E	R	S	Means
Low	15.11	21.67	12.00	14.24	15.76
High	17.39	14.66	17.57	15.22	16.21
Means	16.25	18.17	14.78	14.73	15.98

for further analysis. For example, the average errors for the cylinder and cylindroid are considerably higher than those for the rectangular box and square box, suggesting that the volume of "round" containers is judged less accurately than is that of "square" containers; also, the error for the cylinder is less than that for the cylindroid and that for the square box is less than that for the rectangular box, suggesting that containers whose base dimensions are symmetrical are judged more accurately than those whose dimensions are not symmetrical. The sums of squares for objects were partitioned as shown in Table 9; there, both the roundness-squareness and base symmetry dimensions are found to be significant sources of variance. The roundness-squareness dimension would

seem to be more firmly established by the findings as a meaningful one, while the results for base symmetry appear to be entirely dependent on the greater error found with the cylindroid.

The average errors for the remaining first-order interactions have been plotted in Figures 12, 13, 14, and 15. In general, the conclusion from Figure 12 is that, for the R and S containers, two photographs yield as accurate a judgment as will three or four; while for the C and E containers, three photographs clearly provide more accurate judgments than do two.

Although the N x D interaction is not statistically significant by conventional standards (the F ratio of 2.75 exceeds the tabled value for the 10 percent level of confidence, however), the "damage" curves of Figure 13 offer an indication that, while three photographs provided the most accurate judgment of low-damage containers, four were so required for high-damage containers.

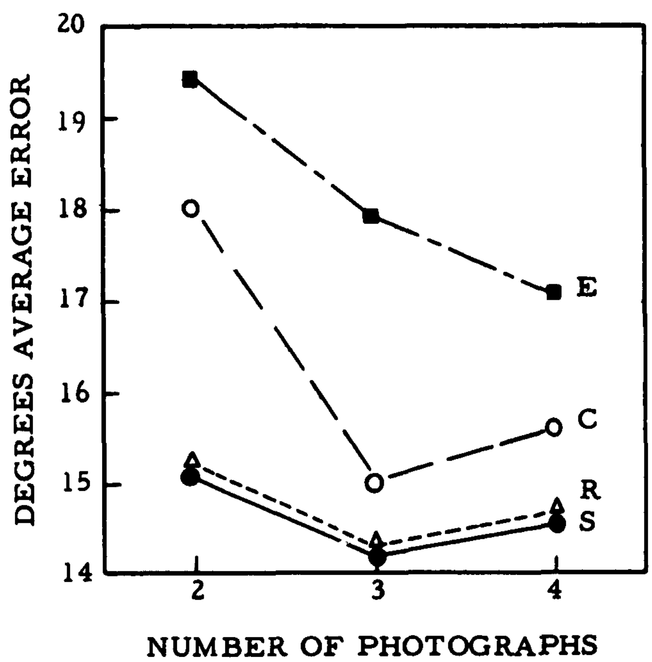

Figure 12. Interaction Between Objects and Number of Photographs.

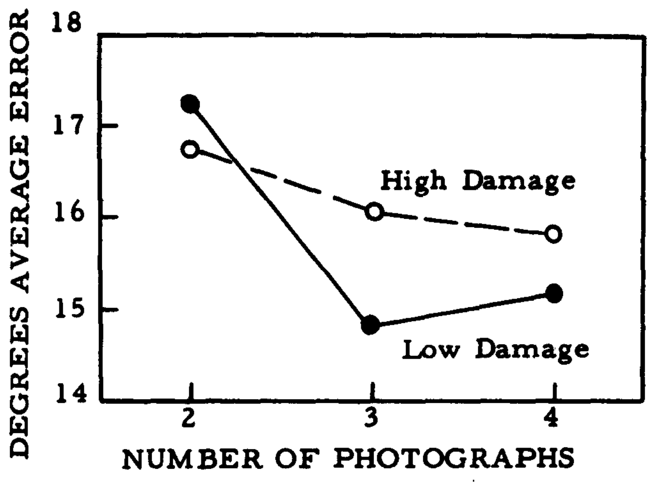

Figure 13. Interaction Between Damage and Number of Photographs.

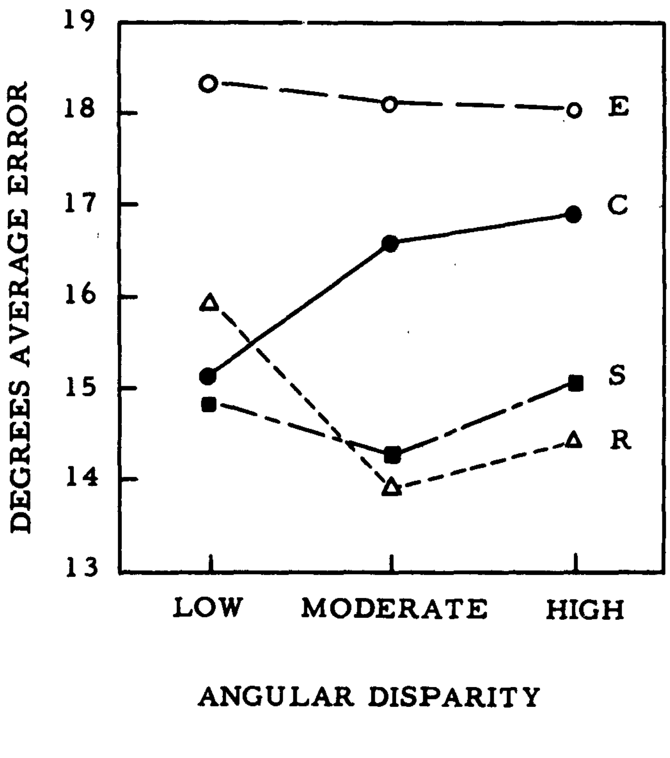

Figure 14. Interaction Between Objects and Angular Disparity.

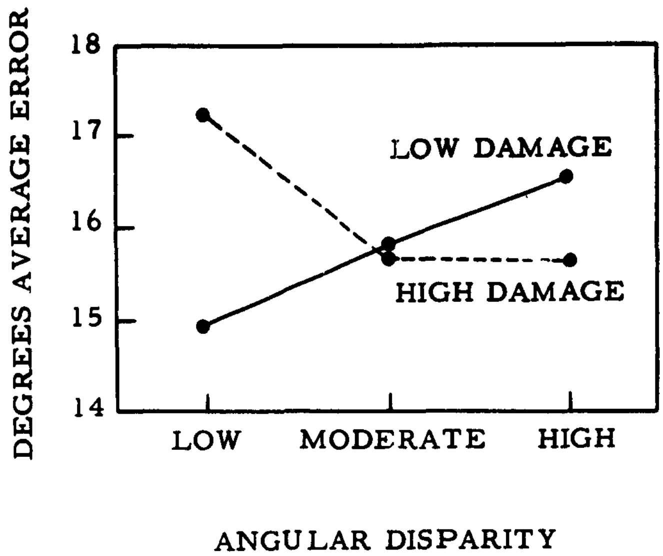

Figure 15. Interaction Between Damage and Angular Disparity.

The conclusion from Figure 14 is that low angular disparity provides the most accurate judgment of C and moderate angular disparity provides the most accurate judgment of R, while accuracy of judgment of E and S is not seen to depend upon angular disparity.

The significant A x D interaction can be attributed to the difference between the values for the low-damage and high-damage curves of Figure 15 at low angular disparity; the differences between the damage values at moderate and high disparity are not statistically significant. The results here indicate that judgments of low damage were made more accurately from groups of photographs having low angular disparity, while judgments of high damage were made more accurately from groups of photographs with moderate or high angular disparity.

The average errors for the two significant higher-order interactions are plotted in Figures 16 and 17. Parenthetically, it should be noted while viewing these interaction curves that the characteristics of a single container, such as R-2, may dominate the picture and thus obscure more general trends. Notwithstanding, these figures clearly emphasize the point that judgmental accuracy does vary in a complex manner, depending upon the type of object, the degree of damage, the number of views available, and the angular disparity between photographs.

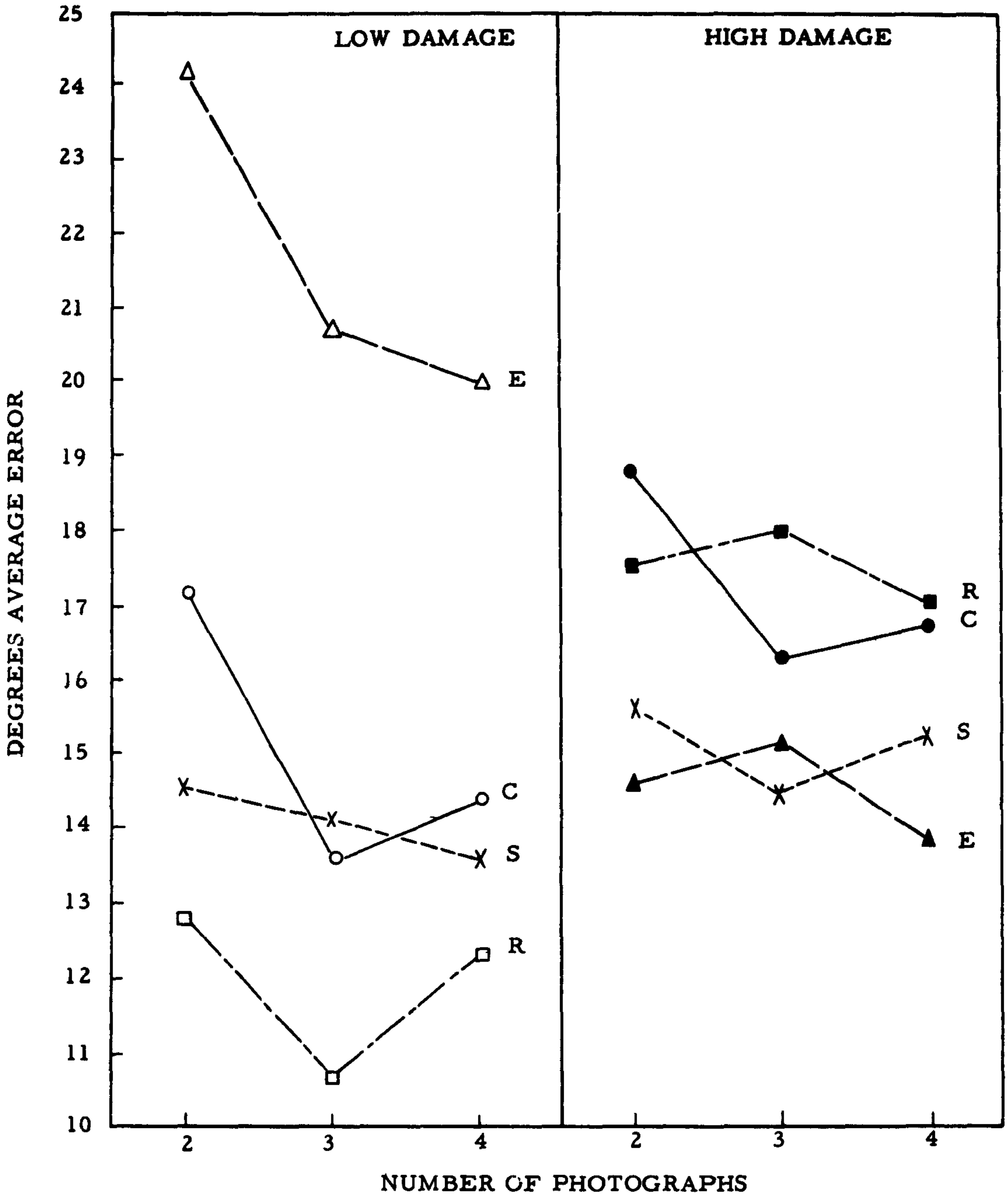

Figure 16. Interaction Between Number of Photographs, Objects, and Damage.

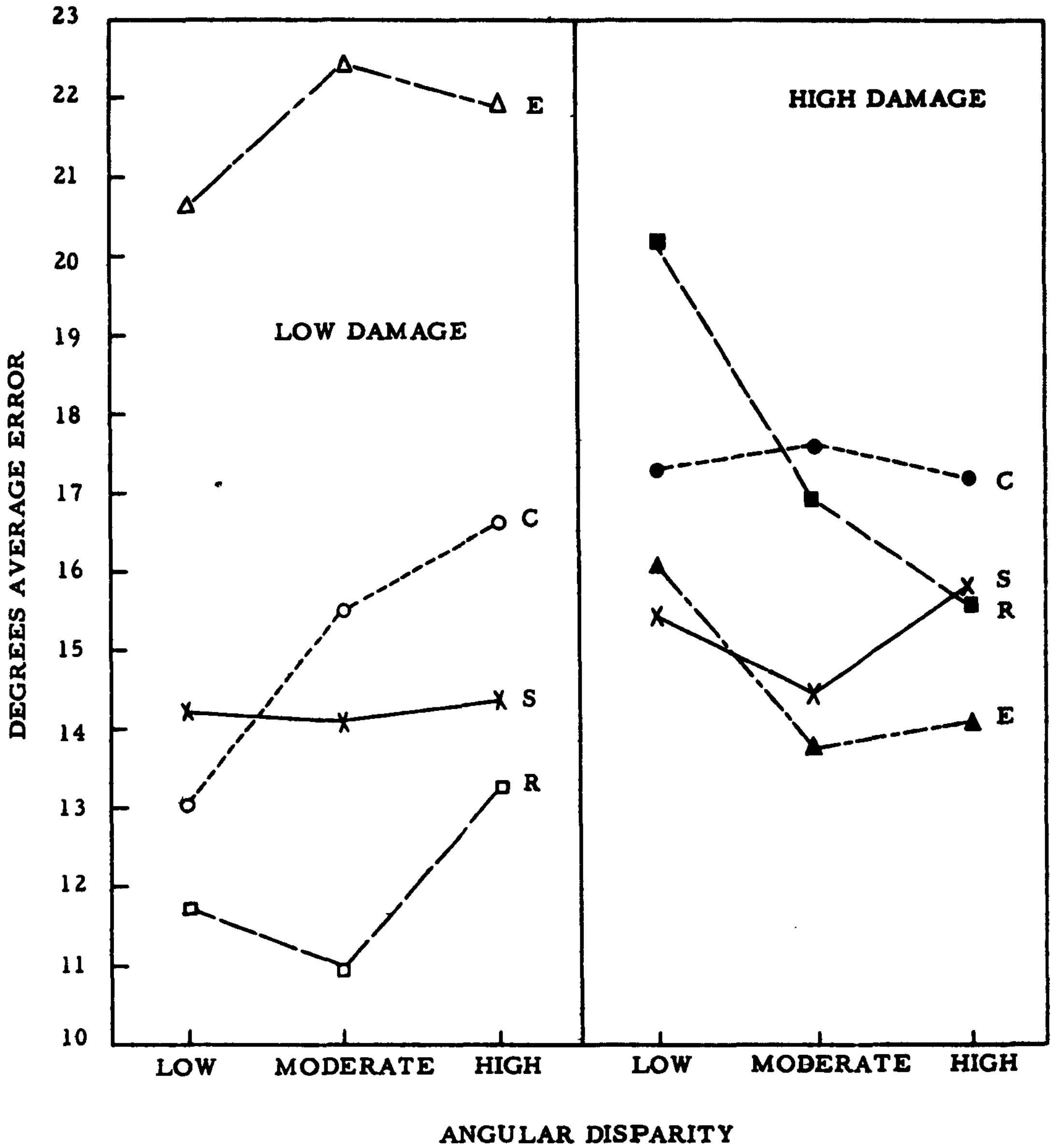

Figure 17. Interaction Between Angular Disparity, Objects, and Damage.

RATER RELIABILITY

Thus far, the findings presented have been relevant to questions of accuracy of judgment. Of related interest are questions of rater reliability. The following approach was taken in test of hypothesis H:3, that individual observers will be consistently high (or low) in their judgment of volume reduction. Product-moment correlation coefficients were computed from the constant errors in judgment for the six possible combinations of the four objects (C, E, R, S) for each of the nine treatment subgroups. The table of 54 coefficients so derived, Table 12, reveals a pattern similar to that previously found with regard to type of objects. In general, the individual subjects were more consistent in their judgment of "square" containers (S, R) as compared with "round" ones (C, E) and, to a greater extent, were more consistent in their judgments of containers having symmetrical bases (S, C) as compared with those having unsymmetrical bases (R, E). But apart from any trend for the correlations to vary with object characteristics, the overall level of these coefficients, around .71, was moderately high and indicates that the intra-rater consistency in judgments was fairly high.

Apart from the question of whether individual observers consistently over- or underestimate the volume reduction of different types of containers is the question of how reliable, in general, are single-observer judgments of volume reduction. The method followed here was that of Ebel (Reference 3, page 395), which assumes that observers involved in the reliability study are interchangeable. The raw data for each of the 36 combinations of four types of objects with the nine treatment subgroups were submitted to analyses of variance in order to obtain the variance estimates required for computation of the single-observer average intercorrelations. The reliability coefficients appear in Table 13 and, on the basis of a chi-square test described by Edwards (Reference 1, page 135), have to be considered as coming from a common population. However, the trends noted previously for the correlations to vary with object characteristics are again found here. The overall level of the coefficients and the estimate of the population value (Reference 1, page 133) are identical: .64. If independent ratings of volume reduction were made by a panel of analysts so that the average ratings would have a reliability of about .95, the number of raters required would be 11. Economical processing of routine accident cases would require a panel of smaller size.

TABLE 12
CORRELATIONAL INDEX OF CONSISTENCY OF RATER OVER- OR UNDERESTIMATION

Angular Disparity		Number of Photographs									
		2			3			4			
		Low	Mod.	High	Low	Mod.	High	Low	Mod.	High	Mean
	SR	.80	.70	.84	.68	.72	.64	.84	.74	.53	.72
	CE	.72	.68	.71	.81	.65	.56	.78	.62	.66	.69
Object Comparisons	SC	.89	.47	.87	.85	.74	.71	.85	.80	.87	.78
	RE	.84	.79	.83	.67	.67	.75	.64	.78	.39	.71
	SE	.68	.65	.70	.77	.51	.50	.72	.74	.66	.66
	RC	.79	.73	.82	.56	.68	.60	.84	.66	.69	.71
	Mean	.79	.67	.80	.72	.66	.63	.78	.72	.63	

TABLE 13
SINGLE-OBSERVER RELIABILITY COEFFICIENTS

Angular Disparity		Number of Photographs									
		2			3			4			
		Low	Mod.	High	Low	Mod.	High	Low	Mod.	High	Mean
	C	.67	.64	.55	.68	.63	.50	.64	.61	.57	.61
	E	.49	.66	.58	.49	.66	.57	.61	.63	.66	.59
Object	R	.48	.69	.70	.59	.65	.70	.57	.59	.66	.63
	S	.78	.78	.59	.70	.74	.63	.72	.73	.69	.71
	Mean	.60	.69	.60	.67	.67	.60	.64	.64	.64	

DISCUSSION

The results presented have shown that the accuracy of observers' judgments of volume reduction vary as a function of the amount of information provided and as an inverse function of the complexity of the stimulus object, thereby lending support to hypotheses H:1 and H:2.

Although angular disparity by itself was not a significant source of variation, it did interact meaningfully with two other variables: objects and damage. The A x D interaction was particularly interesting. If one can equate damage here with complexity, and this does not seem to be an unrealistic comparison to make in this study, then adequate information about the kinds of stimulus shapes used herein is better obtained at low disparities (and perhaps from three photographs) for low-complexity (i.e., low-damage) shapes and at higher disparities (and from four photographs) for high-complexity shapes. In other words, the more complex the shape, the greater information it contains, and thus more and different views are required for valid transmission of this information to the observer.

The differences in observers' judgments as a function of the type of object support hypothesis H:4 with regard to the role played by the geometric characteristics of the object in volume reduction judgments. The partitioning of the sums of squares for objects in the main analysis of variance proved to be fruitful in tentatively establishing two dimensions along which three-dimensional shapes might be scaled. The finding that containers whose base dimensions are symmetrical are judged more accurately than those whose dimensions are not symmetrical <u>may</u> reflect a principle of "good figure." Such a speculation following Gestalt thinking does not say whether (1) observers have a tendency to <u>perceive</u> objects as symmetrical rather than unsymmetrical or (2) observers judge symmetrical objects more accurately because of more valid <u>recall</u> of more familiar objects. The finding that containers that are "square" are judged more accurately than those that are "round" may reflect memory for the computational formulas of solid geometry. Most observers would have little difficulty in conceptualizing the volume computation for a "square" box, would have some difficulty with the cylinder, and would have considerable difficulty with the cylindroid.

Another possible explanation for the findings with regard to type of object involves consideration of the role of size and shape constancy. This view suggests that observers do not, in fact, retain a dimensional impression of the intact, original object (a notion, incidentally, in

accord with the Pretest findings) and so, in this sense, do not "compute" volume reduction. Rather, the object is reconstructed from the dimensions of the immediately present damaged object, and then certain cues relevant to the degree of damage yield the perceptual inputs for the mediation process subserving volume reduction estimation. With this view, the ability to recall the size of the original object is irrelevant--since the scale of measurement in the task (i.e., percent volume reduction) is a relative one--but the ability to recall the shape of the original object is important. Within the context of the present study, the magnitude of the constancy effect may vary with the geometric shape of the object involved (e.g., cylinder, cylindroid, etc.) and so be reflected in the accuracy with which an observer is able to reconstruct the intact object. Thus shape constancy, but not size constancy, would be seen to play an important role in determining the accuracy in judgments of complex, irregular shapes.

A choice between alternative explanations is not to be here resolved, however; rather, to be emphasized is the inadequacy of knowledge in this area and the need for further definitive study of three-dimensional shape perception.

Apart from the role played by different types of objects in judgment of volume reduction, the results of the correlational analysis show that individual observers tend to be consistently high (or low) in their judgments, thereby supporting hypothesis H:3. Insofar as the observer is familiar with damaged objects in general, he might be consistently good in his judgments. A more naive observer in this respect could consistently judge high or low because of some general response tendency or because of some situational bias. A "central tendency" for high-damage stimuli to be underestimated and low-damage stimuli to be overestimated might also have been postulated, but the results failed to give any clearcut evidence of this. In a few cases, the reverse of this tendency was demonstrated.

In conclusion, the ability of observers to estimate the volume reduction of complex, irregular shapes from photographs has been shown to be a function of a number of variables submitted to empirical evaluation in this study. The overall average error in judgment was approximately 16 percent. If our goal is greater reliability and accuracy in judgment, then much additional research is in sight in order to determine the role of additional variables falling within the areas of stimulus attributes, viewing conditions, and observer characteristics.

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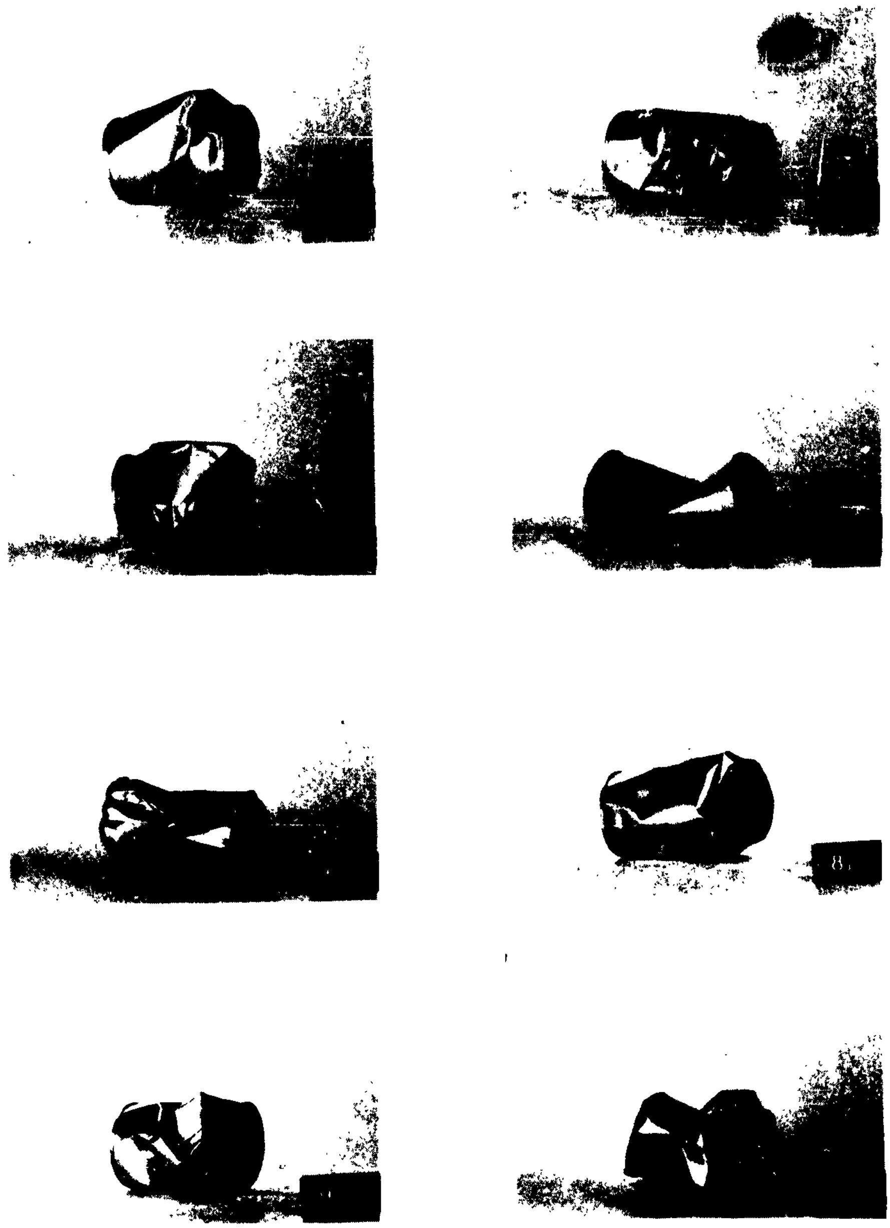

Figure 18. Photographs of Stimuli: Cylinders.

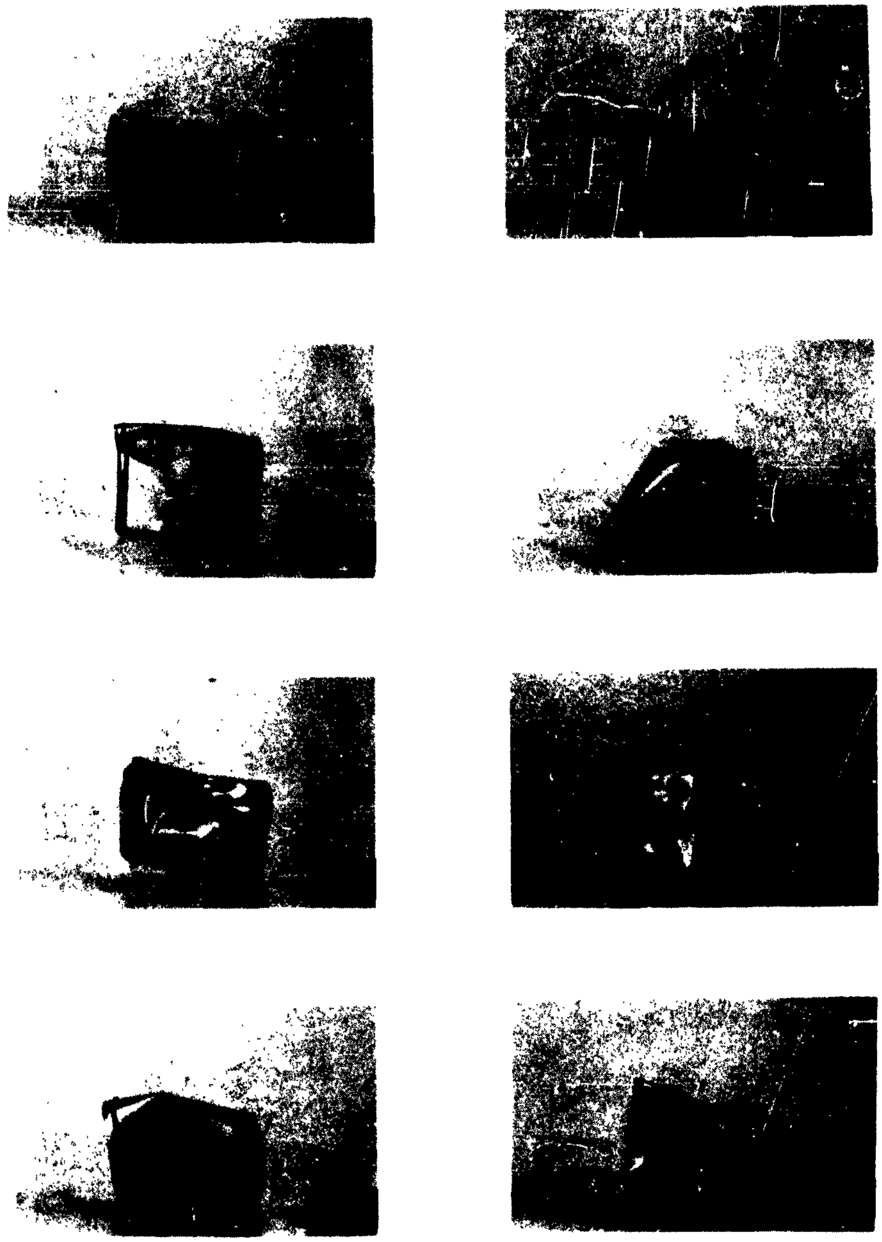

Figure 19. Photographs of Stimuli: Cylindroids.

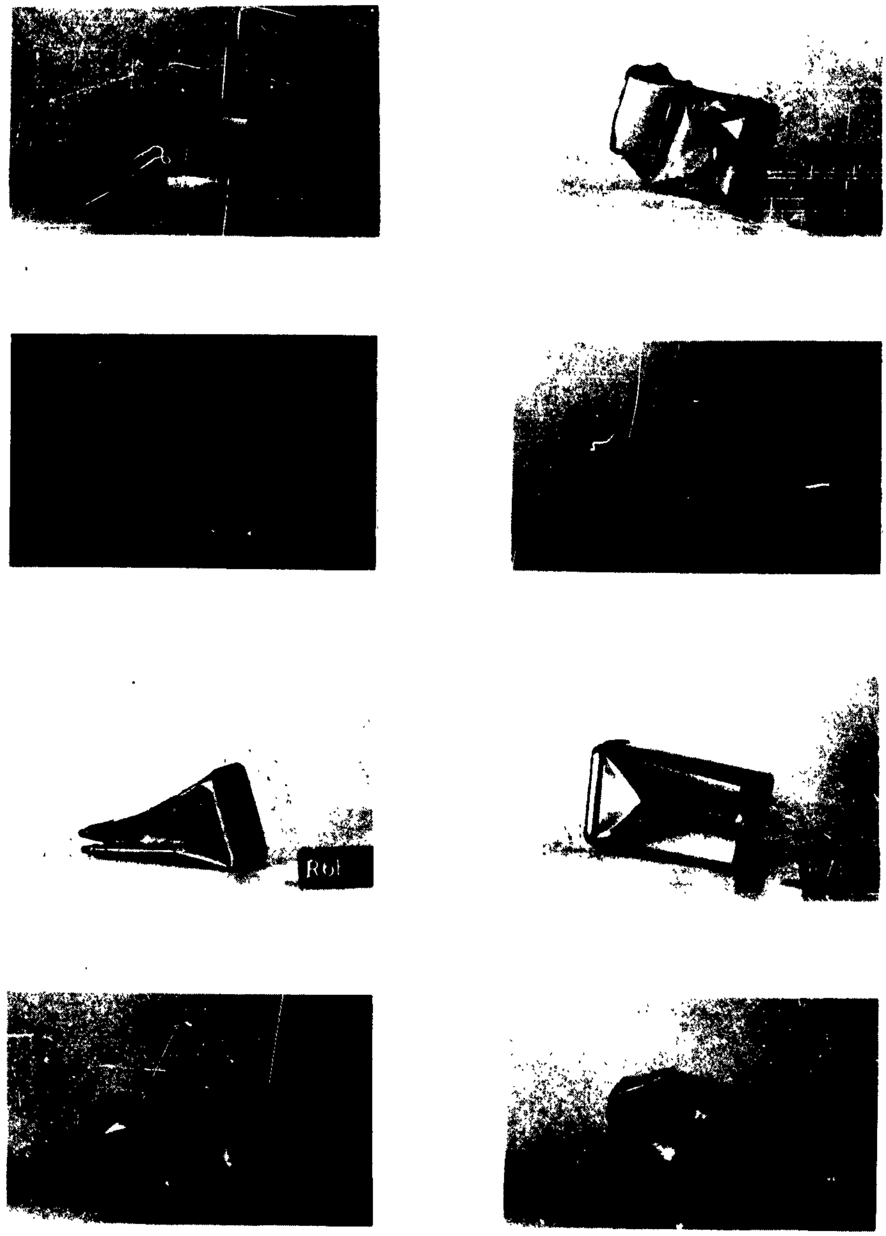

Figure 20. Photographs of Stimuli: Rectangular-Base Boxes.

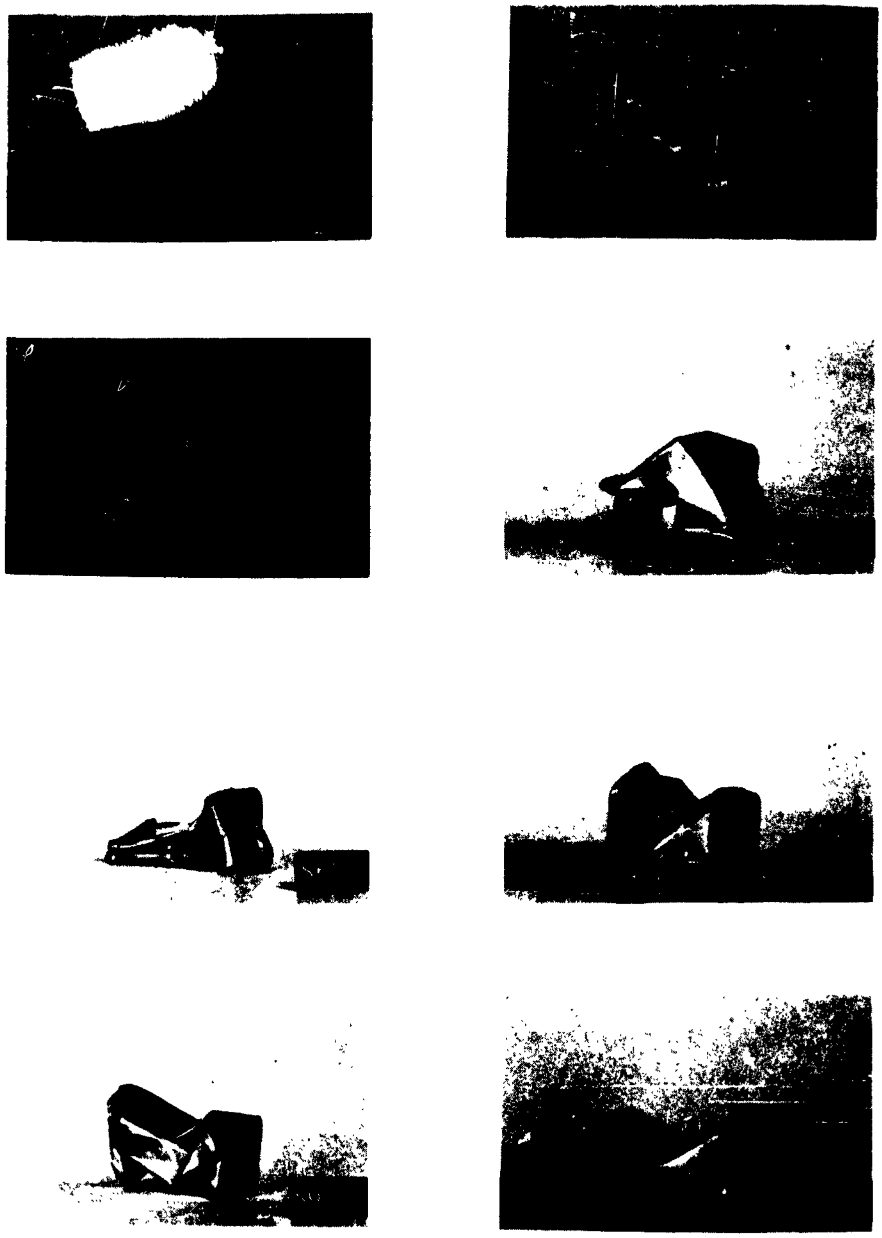

Figure 21. Photographs of Stimuli: Square-Base Boxes.

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Contract DA-44-177-AMC-888(T)
USATRECOM Task 9R95-20-001-01
(Unclassified Report)

This study was concerned with the ability of observers to judge the volume reduction of 40 damaged metal containers from photographs. Hypotheses regarding (Cont'd.)

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